PATENT ABSTRACTS OF JAPAN

(11)Publication number : 11-341153
(43)Date of publication of application : 10.12.1999

(51)Int.Cl. H04M 3/00
H04L 5/16
H04L 7/00
H04L 12/50
H04M 11/06

(21)Application number : 10-144913
(22)Date of filing : 26.05.1998

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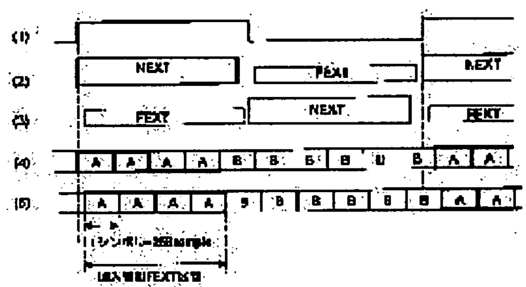
(54) DIGITAL SUBSCRIBER'S LINE TRANSMISSION SYSTEM

(57)Abstract:
PROBLEM TO BE SOLVED: To take the measure of TCM Cross-talk only by changing a part of softwear by informing a subscriber's side ADSL of a specific phase of an ISDN ping-pong by an ADSL on a station side and detecting an NEXT and FEXT section respectively by each ADSL on the station side/subscriber's side.
SOLUTION: At the time of an initial training, an NEXT section and an FEXT section synchronized with a TCM 400 Hz are information of. The information of this 400 Hz is performed from the station side to the subscriber's side, TCM Cross-talk selects a carrier of fewer frequency, two signal points are modulated by shifting a phase by 90 degrees out of signal points of a four value QAM and transmits them. By using the signals different by the 90 degrees, it is possible to discriminate between the NEXT section and the FEXT section by modulated two kinds of signal points having a 90 degrees phase difference even if there is an error in the phase of the modulated signal point.



LEGAL STATUS

[Date of request for examination]

[Date of sending the examiner's decision of rejection]

[Kind of final disposal of application other than the examiner's decision of rejection or application converted registration]

[Date of final disposal for application]

[Patent number]

[Date of registration]

(3)

(19) 日本国特許庁 (JP)　(12) 公開特許公報（Ａ）　(11) 特許出願公開番号

特開平１１－３４１１５３

(43) 公開日　平成11年(1999) 12月10日

(51) Int. Cl.⁶		識別記号	F I			
Ｈ０４Ｍ	3/00		Ｈ０４Ｍ	3/00		C
Ｈ０４Ｌ	5/16		Ｈ０４Ｌ	5/16		
	7/00			7/00		G
	12/50		Ｈ０４Ｍ	11/06		
Ｈ０４Ｍ	11/06		Ｈ０４Ｌ	11/20	１０３	Z

審査請求　未請求　請求項の数１　ＯＬ　（全１１頁）

(21) 出願番号　特願平10-144913

(22) 出願日　平成10年(1998) 5月26日

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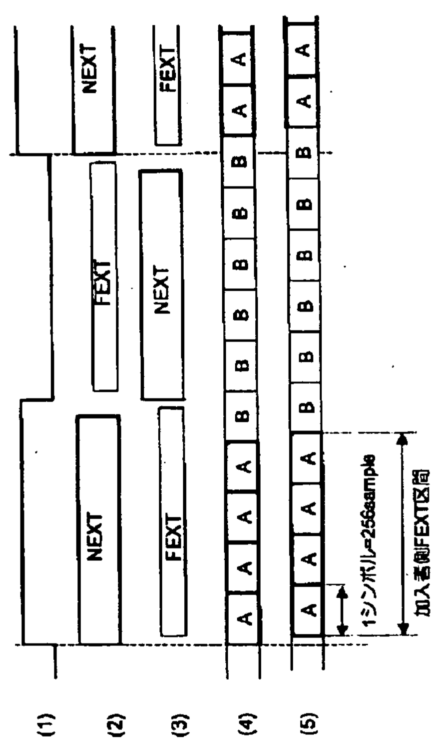
(54)【発明の名称】ディジタル加入者線伝送システム

(57)【要約】

【課題】標準方式と大きく異なることなく、標準方式を採用するハードウェアに対して、ソフトウェアを一部変更することでTCM Cross-talk対策を行うことが可能となる加入者線伝送システムを提供すること。

【解決手段】局側のＡＤＳＬ通信装置がＩＳＤＮピンポンの４００Ｈｚの位相を加入者側ＡＤＳＬ通信装置に通知し、局側／加入者側それぞれのＡＤＳＬ通信装置がそれぞれＮＥＸＴ、ＦＥＸＴ区間を検出できる機構を備える。



同期信号の送信方法

【特許請求の範囲】

【請求項１】電話回線を伝送路とするディジタル加入者線伝送システムにおいて、近接する前記伝送路上のピンポン伝送信号の位相を示す同期信号を対向する加入者側通信装置へ送出する同期手段を局側通信装置に備え、対向する装置における前記近接する伝送路のピンポン伝送信号からの漏話雑音の区間分布を検出する雑音レベル検出手段を前記局側通信装置及び前記加入者側通信装置に備えたことを特徴とするディジタル加入者線伝送システム。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は、既設の電話回線を高速データ通信回線として利用するディジタル加入者線伝送システムに関し、特に上記伝送システムに供される伝送装置の変復調方式の改良に関する。近年、インターネット等のマルチメディア型サービスが一般家庭を含めて社会全体へと広く普及してきており、このようなサービスを利用するための経済的で信頼性の高いディジタス加入者線伝送システムの早期提供が強く求められている。

【０００２】

【従来の技術】［１］ＡＤＳＬ技術の説明

既設の電話回線を高速データ通信回線として利用する加入者線伝送システムを提供する技術としては、ｘＤＳＬ(Digital Subscriber Line)が知られている。ｘＤＳＬは電話回線を利用した伝送方式で、かつ、変復調技術の一つである。このｘＤＳＬは、大きく分けて加入者宅（以下、加入者側と呼ぶ。）から収容局（以下、局側と呼ぶ）への上り伝送速度と、局側から加入者側への下り伝送速度が対称のものと、非対称のものに分けられる。

【０００３】非対称型のｘＤＳＬにはＡＤＳＬ（Asymmetric DSL）があり、下り伝送速度が６Ｍビット／秒程度のＧ．ＤＭＴと１．５Ｍビット／秒程度のＧ．ｌｉｔｅがあるが、どちらも変調方式としてＤＭＴ（Discrete Multiple Tone）変調方式を採用している。

［２］ＤＭＴ変調方式の説明

ＤＭＴ変調方式をＧ．ｌｉｔｅを例にとり、図１１を用いて説明する。また、本説明および説明図は局から加入者への下り方向の変復調についてのみ記す。

【０００４】まず、装置に送信データが入力されSerial to Parallel Buffer １０に１シンボル時間（１／４ｋＨｚ）分ストアされる。ストアされたデータは送信ビットマップ６０（後述）で前もって決められたキャリア当たりの伝送ビット数毎に分割して、Encoder ２０に出力する。Encoder ２０では入力されたビット列をそれぞれ直交振幅変調するための信号点に変換してIFFT３０に出力する。IFFT３０は逆高速フーリエ変換を行うことでそれぞれの信号点について直交振幅変調を行い、Parallel to Serial Buffer ４０に出力する。ここで、IFFT出力の２４０～２５５ポイントの１６ポイントをCyclic Prefix としてＤＭＴシンボルの先頭に加える。Parallel to Serial Buffer ４０からD/A Converter ５０へ１．１０４ＭＨｚのサンプリング周波数でアナログ信号に変換され、メタリック回線１００を経由して加入者側に伝送される。

【０００５】加入者側では、A/D Converter １１０により、１．１０４ＭＨｚのディジタル信号に変換され、Serial to Parallel Buffer １２０に１ＤＭＴシンボル分ストアされる。同BufferでCyclic Prefix が除去され、FFT １３０に出力される。FFT １３０では高速フーリエ変換を行い、信号点を発生（復調）する。復調した信号点はDecoder １４０により送信ビットマップ６０と同じ値を保持している受信ビットマップ１６０に従ってデコードする。デコードしたデータはParallel toSelial Buffer １５０にストアされ、ビット列として受信データとなる。

［３］ビットマップの詳細説明

ＤＭＴ変調方式で記したビットマップについて、図１２を用いて、より詳細に説明する。

【０００６】局側の装置と加入者側の装置は、通信を行うためのトレーニング時に回線の変調信号とノイズの比（以下、Ｓ／Ｎと呼ぶ。）を測定し、各変調キャリアで伝送するビット数を決定する。図１２に示すように、Ｓ／Ｎが大きいキャリアでは伝送ビット数を多く割り当て、Ｓ／Ｎが小さいところでは伝送ビット数を少なく割り当てる。

【０００７】これにより、受信側では測定したＳ／Ｎから、キャリア番号に対応した伝送ビット数を示すビットマップが作成される。受信側ではこのビットマップをトレーニング中に送信側に通知することで、定常のデータ通信時に送受信側とも同じビットマップを用いて変復調を行うことが可能となる。

［４］ＩＳＤＮピンポン伝送からの漏話対策

ＩＳＤＮピンポン伝送からの漏話（以下、TCM Cross-talkと呼ぶ。）がある場合に、ＡＤＳＬでは前述のビットマップを２個使用することで伝送特性を向上しようとしていた。このビットマップを２個使用する方法を図１３を用いて説明する。

【０００８】ＩＳＤＮピンポン伝送では、図１３に示す４００Ｈｚに同期して、局側が４００Ｈｚの前半のサイクルで下りデータを送信し、加入者側は下りデータ受信後、上りデータを送信する。このため、局側のＡＤＳＬでは４００Ｈｚの前半のサイクルでＩＳＤＮからの近端漏話（以下、ＮＥＸＴと呼ぶ。）の影響を受け、後半のサイクルで加入者側ＩＳＤＮの上りデータからの遠端漏話（以下、ＦＥＸＴと呼ぶ。）の影響を受ける。

【０００９】加入者側ＡＤＳＬでは、局とは逆に４００Ｈｚの前半でＦＥＸＴの影響を受け、後半のサイクルでＮＥＸＴの影響を受ける。局と加入者の間のメタリッ

クケーブルが長くなると、受信信号とＮＥＸＴとのＳ／Ｎが小さくなり、場合によっては受信信号よりもＮＥＸＴのほうが大きくなる。

【００１０】この場合でもＦＥＸＴの影響はあまりないことから、従来はＮＥＸＴ区間受信用のビットマップ（ＤＭＴシンボルＡ）と、ＦＥＸＴ区間受信用のビットマップ（ＤＭＴシンボルＢ）を２個用意して、ＮＥＸＴ区間では伝送ビット数を小さくして、Ｓ／Ｎ耐力を向上し、ＦＥＸＴ区間で伝送ビット数を大きくして、伝送容量を大きくする手法を採っていた。

【００１１】また、このとき、４００ＨｚのTCM Cross-talkの周期に合わせるため、本来なら１６ポイントのCyclic Prefix で１ＤＭＴシンボル当たり２４６μＳであるのに対し、Cyclic Prefix を２０ポイントとして、１ＤＭＴシンボル当たり２５０μＳとし、TCM Cross-talkの１周期とＤＭＴシンボル１０個分の時間を合わせてTCM Cross-talkに同期していた。

【００１２】

【発明が解決しようとする課題】しかしながら、上述のビットマップを使う方法では標準方式である１個のビットマップを使う方法と大きく異なる。ビットマップを２個使うことにより、トレーニングで受信側がＳ／Ｎから求めたビットマップを送信側に通知するシーケンスを変更しなければならず、加えて、通知時間も２倍となりトレーニング時間の増大を招く。

【００１３】装置を作る上でもビットマップを記憶するためのメモリ容量が大きくなり、コスト上問題である。また、Cyclic Prefix 長を変更することも標準方式と大きく異なり、標準方式を採用する装置のハードウェアで上述のTCM Cross-talk対策を行うことは不可能である。

【００１４】したがって、本発明は標準方式と大きく異なることなく、標準方式を採用するハードウェアに対して、ソフトウェアを一部変更することでTCM Cross-talk対策を行うことが可能となる加入者線伝送システムを提供することを目的とする。また、本発明の別の目的は、TCM Cross-talkがあるなしに依らず最適な伝送速度で通信可能な加入者線伝送システムを提供することを目的とする。

【００１５】

【課題を解決するための手段】本発明は、電話回線を高速データ通信回線としても利用するディジタル加入者線伝送システムにおいて、局側のＡＤＳＬがＩＳＤＮピンポンの４００Ｈｚの位相を加入者側ＡＤＳＬに通知し、局側／加入者側それぞれのＡＤＳＬがそれぞれＮＥＸＴ、ＦＥＸＴ区間を検出できる機構を持つことを特徴としている。

【００１６】また、本発明では、TCM Cross-talkと受信信号のＳ／Ｎのにより最適な伝送容量を確保する伝送方法を決定することを特徴としている。

【００１７】

【発明の実施の形態】以下、図面を参照しながら本発明の実施例を説明する。図１は、初期トレーニング時に、ＴＣＭ　４００Ｈｚに同期したＮＥＸＴ区間とＦＥＸＴ区間を通知するシンボルを示している。この４００Ｈｚの通知は、局側から加入者側に対して行い、TCM Cross-talkが少ない周波数のキャリアを選択して、４値ＱＡＭの信号点のうち、位相を９０°ずらした２つの信号点を変調して伝送する。

【００１８】加入者側は初期トレーニング時、ＤＭＴシンボル境界が分からないため、復調するためのＦＦＴ区間を正しくＤＭＴシンボル区間に合わせることができない。このため、復調後の信号点が正しい位相（象限）に現れないが、９０°異なる信号を用いることにより、復調した信号点の位相は誤りがあっても、復調した２種類の信号点が９０°の位相差を持つことによりＮＥＸＴ区間ＦＥＸＴ区間を識別することが可能となる。

【００１９】図２は、前述の４００Ｈｚ情報を伝送する際の、ＮＥＸＴ区間とＦＥＸＴ区間を定義している。局側ＡＤＳＬは１度４００Ｈｚの位相を検出した後、サンプル単位でカウントするＤＭＴシンボルカウンターとＮＥＸＴ／ＦＥＸＴ区間を識別するカウンターを動作させることにより、ＤＭＴシンボルを４００Ｈｚに合わせることなくＤＭＴシンボルがＮＥＸＴ／ＦＥＸＴのどちらの区間に該当するかを識別できる。

【００２０】図２では、ＮＥＸＴ区間、ＦＥＸＴ区間の定義で、ＮＥＸＴ／ＦＥＸＴ区間を識別するカウンターの値を定義しており、この値はＩＳＤＮ　ピンポン伝送の伝達遅延により発生するラウンドトリップディレイも考慮する値とする。1 シンボル目のDMT シンボルが400Hz の先頭に同期している場合, n個目のシンボルが加入者側で何れの区間となるかは次式で与えられる。

【００２１】S = (256 * (n-1)) mod 2760

としたとき

if { (S < (a-256)) or (S > (a+b))} then FEXT区間

if { (a-256)≦ S≦ (a+b)} then NEXT 区間

図３は、トレーニングシーケンスの切り換えを示す信号を送信するタイミングを示している。

【００２２】ＡＤＳＬでは、トレーニングシーケンスを切り換えるタイミングを相手側へ通知するためにシーケンス切り換えシンボルを送信することにより行っている。このとき、シーケンス切り換えシンボルの先頭を受信側が認識できないと、トレーニングを正常に行うことが不可能となる。このため、シーケンスの切り換えを相手側へ確実に通知するために、受信側がＦＥＸＴ区間にシーケンス切り換えシンボルの先頭をを受信できるようなタイミングで送信する。

【００２３】図３では局側から加入者側へ通知する場合を示している。ＡＤＳＬでは、また、トレーニング中に受信信号から各変調キャリア毎のＳ／Ｎを測定して各変

調キャリア毎に伝送するビット数を決定する。TCM Cross-talk環境下では、このＳ／Ｎの測定もＮＥＸＴ、ＦＥＸＴの影響を考慮して、ＮＥＸＴ区間、ＦＥＸＴ区間毎にＳ／Ｎを測定しなければならない。

【００２４】図４では、このＳ／Ｎ測定用のＮＥＸＴ区間、ＦＥＸＴ区間を定義している。ＮＥＸＴ区間で測定したＳ／Ｎから算出した伝送ビット数は、ＮＥＸＴ区間で、前もって決められたビットエラーレート（以下、ＢＥＲと呼ぶ。）を保証できる値でなくてはならない。このため、図４に示すように、ＮＥＸＴ区間でＳ／Ｎを測定するＤＭＴシンボルは、そのシンボル全てがＮＥＸＴ区間に入っているもののみを用いる。ＦＥＸＴ区間でのＳ／Ｎの測定も同様にそのシンボル全てがＦＥＸＴ区間に入っているもののみを用いる。また、ＮＥＸＴ区間もしくは、ＦＥＸＴ区間に完全に入らないＤＭＴシンボルは、伝送ビット数を決定するための情報としては意味を持たないため、Ｓ／Ｎ計算の対象外とする。

【００２５】1 シンボル目のDMT シンボルが受信400Hzの先頭に同期している場合,n個目のシンボルを何れの区間としてS/N 計算を行うかは次式で与えられる。

S = (272 * (n-1)) mod 2760としたとき

if { (S < (a-272)) or (S > (a+d+e+f))} then FEXT 区間(B区間用S/N 測定)

if { (a+d) < S < (a+d+e-272)} then NEXT区間 (A区間用S/N 測定)

何れの条件も満たさない受信シンボル→ S/N測定対象外

なお, d+e+f は図2,図10のb に等しい。

【００２６】図５に加入者側ＡＤＳＬでＳ／Ｎを測定する形態を示す。受信データが復調器２１０に入り復調デ＊ータとして各キャリア毎の信号点を出力する。また、リファレンス２２０からは本来受信すべきキャリア毎の信号点が出力される。このリファレンスからの信号点と復調した信号点の差をＥＲＲＯＲとし各キャリア毎のＥＲＲＯＲをセレクタ２６０に入力する。

【００２７】また、装置内クロック２３０を分周器２４０で４００Ｈｚに分周して、位相判定器２５０に入力する。ここで、４００Ｈｚは復調器から局側で伝送された４００Ｈｚの情報により、位相が前もって局側の４００Ｈｚと合わされている。位相判定器２５０では入力された４００Ｈｚにより、受信したＤＭＴシンボルがＦＥＸＴ区間かＮＥＸＴ区間かそれ以外かを判定し、セレクタ２６０に入力する。セレクタ２６０では、前述の入力されたＥＲＲＯＲを判定器から入力された情報によりＮＥＸＴ区間Ｓ／Ｎ測定器２７０もしくはＦＥＸＴ区間Ｓ／Ｎ測定器２８０へ出力する。各Ｓ／Ｎ測定器はＥＲＲＯＲを積分してＳ／Ｎを算出して、それぞれ、各キャリア毎に伝送ｂｉｔ数換算器２９０に出力する。伝送ｂｉｔ数換算器２９０では、入力された各キャリア毎のＳ／Ｎから各キャリア毎に伝送するビット数（ビットマップ）を算出し、ＮＥＸＴ区間用のビットマップｂ－ＮＥＸＴとＦＥＸＴ区間用のビットマップのｂ－ＦＥＸＴを出力する。

【００２８】受信側ＡＤＳＬは、伝送速度を、このｂ－ＮＥＸＴとｂ－ＦＥＸＴから算出する。つまり、ｂ－ＦＥＸＴ区間の値はＦＥＸＴ区間のみ受信可能な伝送ビット数であること、ｂ－ＮＥＸＴは全ての区間で受信可能な伝送ビット数であることから、＊

伝送速度１　＝　（ｂ－ＦＥＸＴのトータルビット数）×α×変調速度

伝送速度２　＝　（ｂ－ＮＥＸＴのトータルビット数）×１．０×変調速度

の２つの値を求めて、大きいほうの伝送速度で通信することを決める。

【００２９】ここで、ビットマップｂ－ＮＥＸＴを用いて全区間でデータ伝送する方式を標準方式と呼び、ビットマップｂ－ＦＥＸＴを用いてＦＥＸＴ区間のみ伝送する方法をスライディング・ウィンドウ・ビットマップ（以下、ＳＷＢと呼ぶ。）方式と呼ぶ。ここで、標準方式とＳＷＢ方式の伝送速度を図６のグラフに示す。

【００３０】図６ではTCM Cross-talkがある環境下では、標準方式は、回線が長くなるとＮＥＸＴの影響が大きくなり、伝送容量が極端に減っていくが、ＳＷＢ方式では、回線の距離が短い場合は伝送速度が大きくないものの、距離が長くなっても伝送容量が落ちないことを示している。図７に標準方式とＳＷＢ方式の送信ビットマップを示す。

【００３１】図７では、前述のｂ－ＮＥＸＴをビットマップＡ、ｂ－ＦＥＸＴをビットマップＢとして送信ビットマップを示している。ＳＷＢ方式では図に示すように、送信側はＮＥＸＴ区間のみ、つまり受信側がＦＥＸＴ区間であるときに、伝送ビットを各キャリアに割りつけるようにウィンドウをスライドさせ、受信側ではＦＥＸＴ区間に受信データを復調するようにウインドウをスライドする。

【００３２】また、ＳＷＢ方式でのスライディング・ウィンドウの外側のＤＭＴシンボルの送信波形はタイミング同期用のパイロット・トーンを送信することとし、それ以外のキャリアは任意とする。図８にＳＷＢ方式の局側伝送パターンを示す。ＡＤＳＬでは、ＤＭＴシンボル６９個を１つのＳｕｐｅｒ　Ｆｒａｍｅとして、６９番目にはＳｕｐｅｒ　Ｆｒａｍｅ境界を示す、ユーザーデータを含まないＳｙｎｃ　Ｓｙｍｂｏｌを伝送している。

【００３３】ＳＷＢ方式では、このＳｕｐｅｒ　Ｆｒａｍｅ５個を１つの単位とし、４００Ｈｚ（２．５ｍＳ）の整数倍に合わせて、局側と加入者側のスライディング・ウィンドウを同期させる。また、このＳｕｐｅｒ　Ｆｒａｍｅ５個の境界を加入者側に送信するために、５個あるＳｙｎｃ　Ｓｙｍｂｏｌのうち、４番目のＳｙｎｃ

ＳｙｍｂｏｌをＩｎｖｅｒｓｅ　Ｓｙｎｃ　Ｓｙｍｂｏｌとして、ＳｙｎｃＳｙｍｂｏｌの１８０°信号点を回転したものを送信する。４番目に送信することで、加入者側はＦＥＸＴ区間にこのＳｙｍｂｏｌを受信でき、確実に加入者側が局のＳＷＢに同期することが可能となる。同様に図９にＳＷＢ方式の加入者側伝送パターンを示す。

【００３４】加入者側の伝送パターンは前述の局側伝送パターンと対をなしており、局側がＦＥＸＴ区間に受信できるようにスライデイング・ウィンドウを合わせる。また、局側と同様にＳｕｐｅｒ　Ｆｒａｍｅ５個を１つの単位とするが、境界を局側へ通知するために、５個あるＳｙｎｃ　Ｓｙｍｂｏｌのうち、１番目のＳｙｎｃＳｙｍｂｏｌをＩｎｖｅｒｓｅ　Ｓｙｎｃ　Ｓｙｍｂｏｌとして、ＳｙｎｃＳｙｍｂｏｌの１８０°信号点を回転したものを送信する。１番目に送信することで、局側はＦＥＸＴ区間にこのＳｙｍｂｏｌを受信でき、局側は加入者側が正しくＳＷＢを同期していることを検出することが可能となる。図１０は、通信状態における送信シンボルの雑音区間を定義している。

【００３５】通信状態ではＤＭＴシンボル内のＣｙｃｌｉｃ　Ｐｒｅｆｉｘを除いた部分が全てＦＥＸＴ区間に入る場合をＦＥＸＴ区間のＤＭＴシンボルと定義し、それ以外をＮＥＸＴ区間のＤＭＴシンボルとして定義している。また、ここでの区間定義は前述のラウンドトリップディレイを考慮し、かつシステムマージンを考慮した値とする。

【００３６】1 シンボル目のDMT シンボルが400Hz の先頭に同期している場合,n個目のシンボルが加入者側で何れの区間となるかはcyclic prefix を除いたDMT シンボルがNEXT区間に入るかどうかで決定されるため，次式で表現される。

S = (272 * (n-1)) mod 2760としたとき

if { (S < (a-272)) or (S+16 > (a+b)) } then FEXT 区間 (B 区間)

if { ((a-272) ≦ S) and (S+16 ≦ (a+b)) } then NEXT区間 (A 区間)

図１１にスライディング・ウィンドウ外も伝送ビットをマッピングする方法を示す。スライデイング・ウインドウの外側も伝送ビットを割りつける場合、図１１に示すようにビットマップを２個使い、ＮＥＸＴ区間受信用ビットマップとＦＥＸＴ区間受信用ビットマップを使用して、データ伝送を行う。

【００３７】

【発明の効果】

【図面の簡単な説明】

【図１】同期信号の送信方法を示す図である。

【図２】初期トレーニング時の雑音区間通知のためのシンボルパターン定義を示す図である。

【図３】シーケンス切り換えシンボルの送出タイミングを示す図である。

【図４】S/N 測定時における受信シンボルの雑音区間定義を示す図である。

【図５】NEXT/FEXT 区間毎にS/N を測定する形態を示す図である。

【図６】伝送容量比較を示す図である。

【図７】標準方式/SWB方式の選択による送信ビットマップを示す図である。

【図８】SWB 方式の局側伝送パターンを示す図である。

【図９】SWB 方式の加入者側伝送パターンを示す図である。

【図１０】通信状態時における送信シンボルの雑音区間定義を示す図である。

【図１１】ビットマップを2 個使用する場合のSWB 方式を示す図である。

【図１２】DMT 変調方式による加入者伝送システムの機能ブロックを示す図である。

【図１３】ビットマップの定義を示す図である。

【図１４】従来例を示す図である。

【図１５】DMT シンボル毎の送信パターンを示す図

【符号の説明】

２１０…復調器

２２０…リファレンス

２６０…セレクタ

２３０…装置内クロック

２４０…分周器

２５０…位相判定器

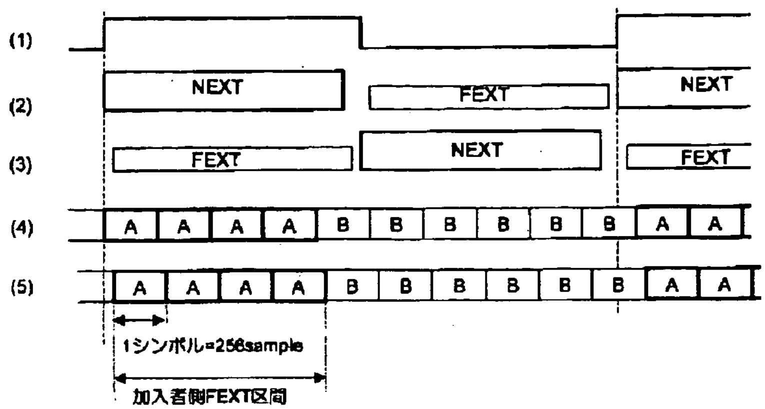
２６０…セレクタ

２７０…ＮＥＸＴ区間Ｓ／Ｎ測定器

２８０…ＦＥＸＴ区間Ｓ／Ｎ測定器

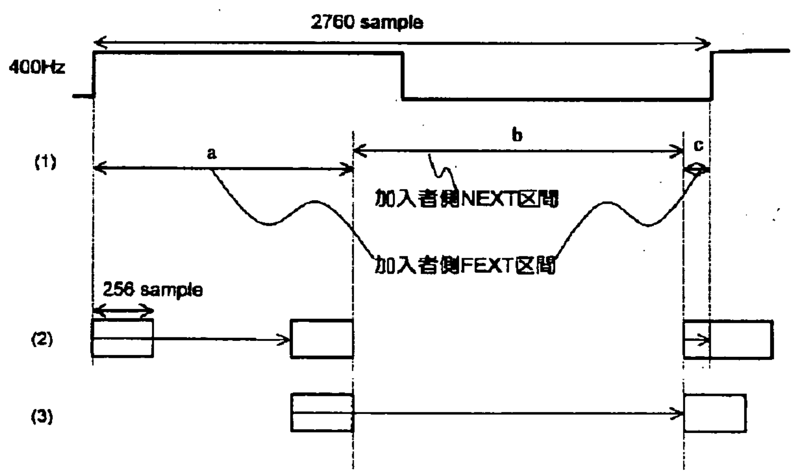
２９０…伝送ｂｉｔ数換算器

【図１】



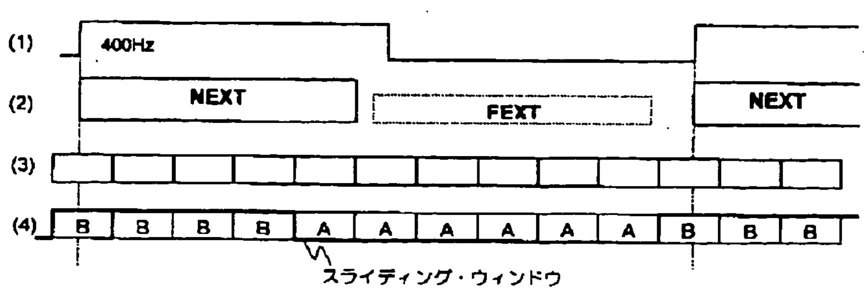
同期信号の送信方法

【図２】



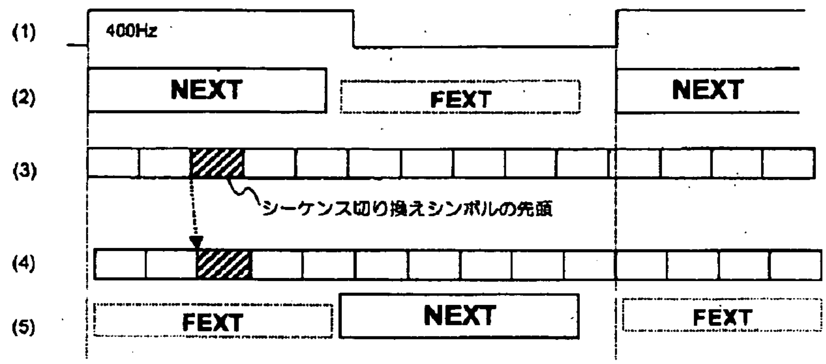
初期トレーニング時の雑音区間通知のためのシンボルパターン定義

【図１１】



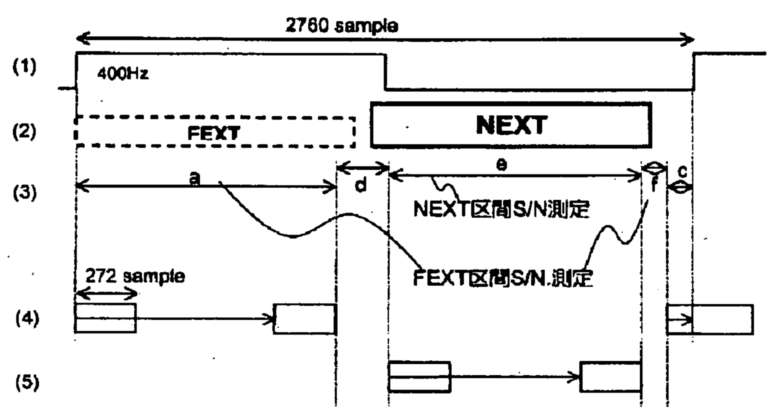
ビットマップを2個使用する場合のSWB方式

【図３】



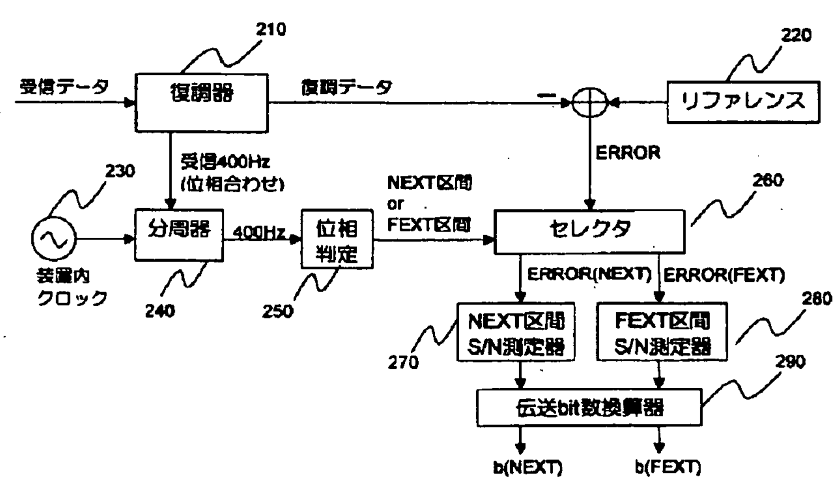
シーケンス切り換えシンボルの送出タイミング

【図４】



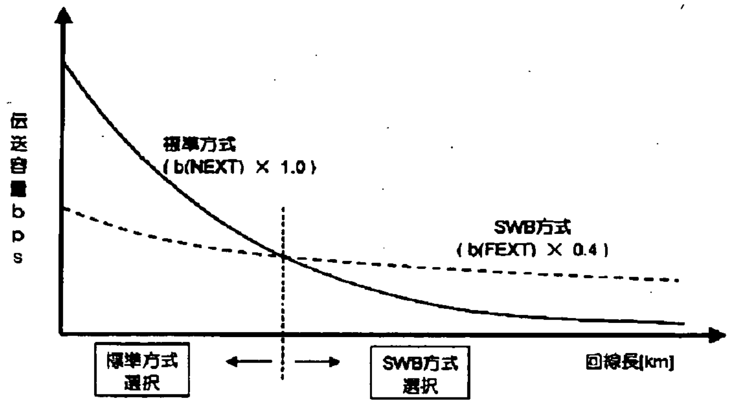
S/N測定時における受信シンボルの雑音区間定義

【図５】



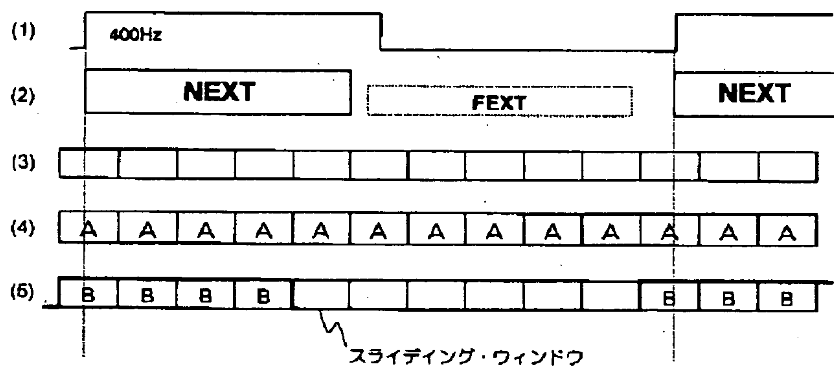
NEXT/FEXT区間毎にS/Nを測定する形

【図6】



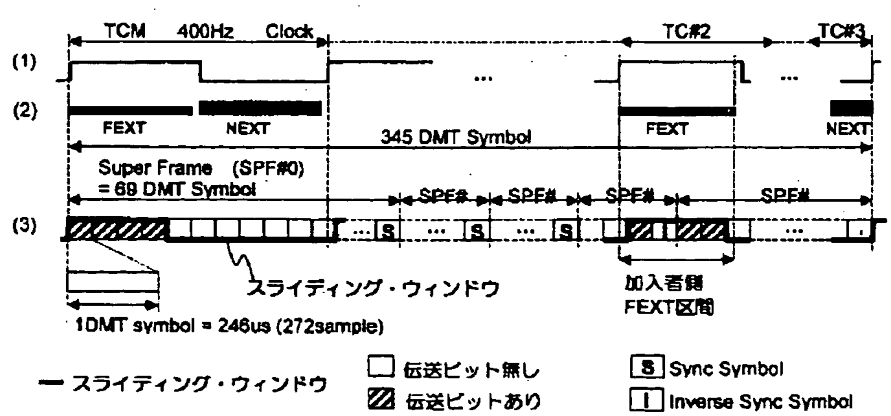
伝送容量比較

【図7】



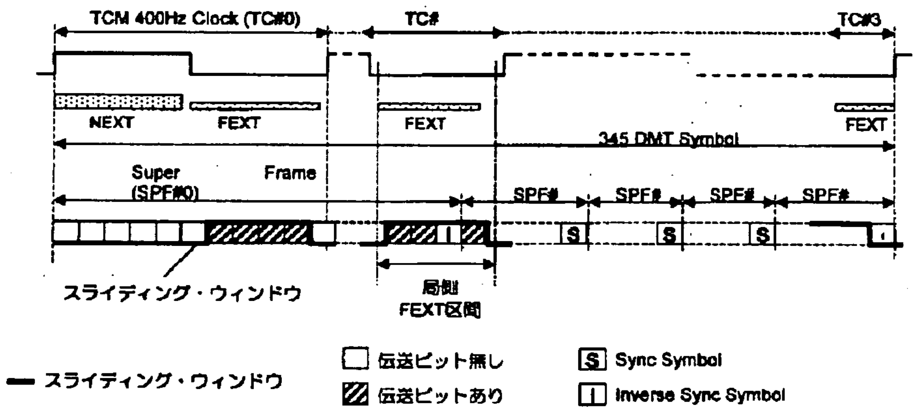
標準方式/SWB方式の選択による送信ビットマップ

【図8】



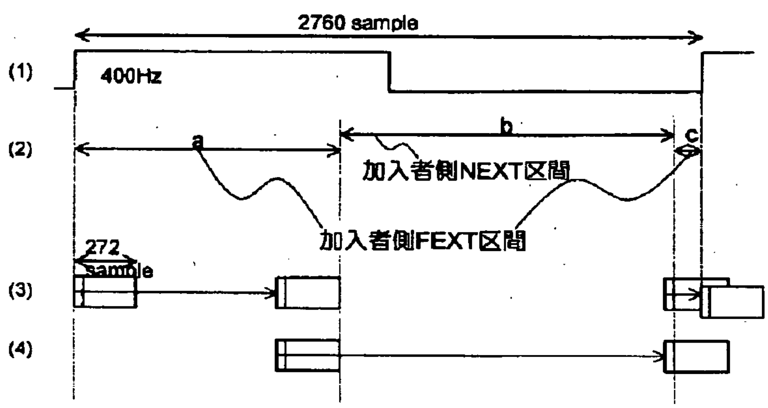
SWB方式の局側伝送パターン

【図９】



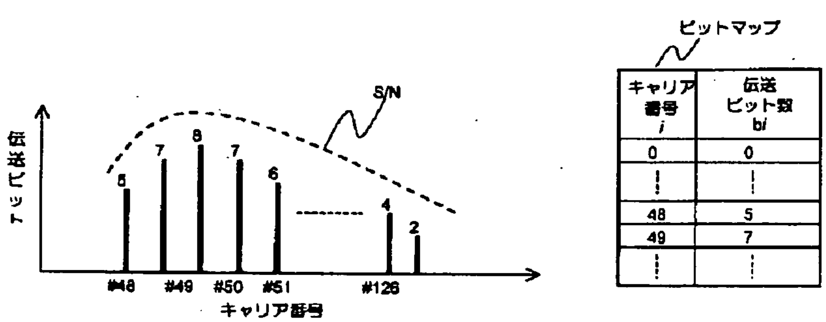
SWB方式の加入者側伝送パターン

【図１０】



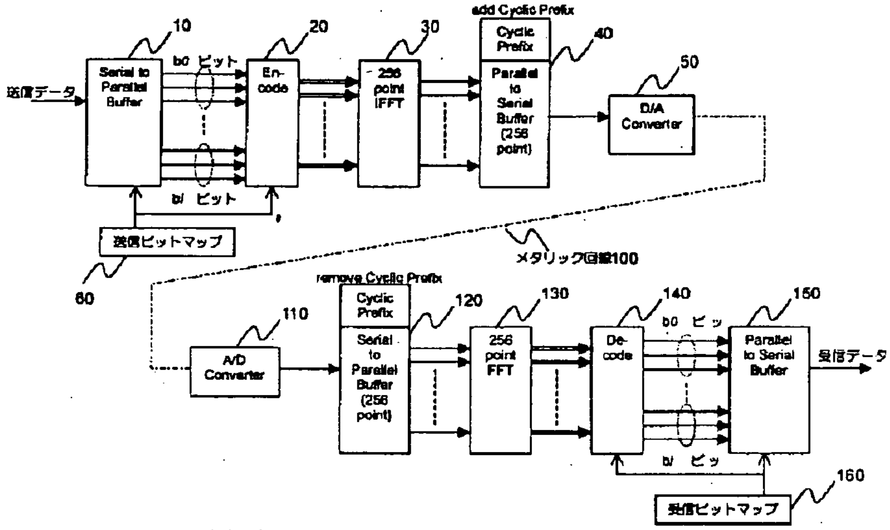
通信状態時における送信シンボルの雑音区間定

【図１３】



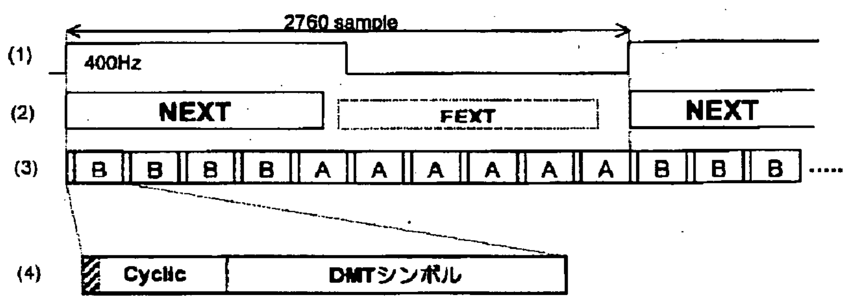
ビットマップの定義

【図１２】



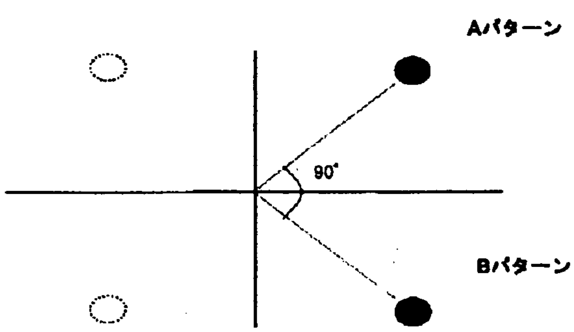
DMT変調方式による加入者伝送システムの機能ブロック

【図１４】



従来例

【図１５】



DMTシンボル毎の送信パターン

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(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 961 449 A2

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
01.12.1999 Bulletin 1999/48

(51) Int. Cl.^{6}: **H04L 27/26**

(21) Application number: **99109253.7**

(22) Date of filing: **26.05.1999**

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: **26.05.1998 JP 14491398**

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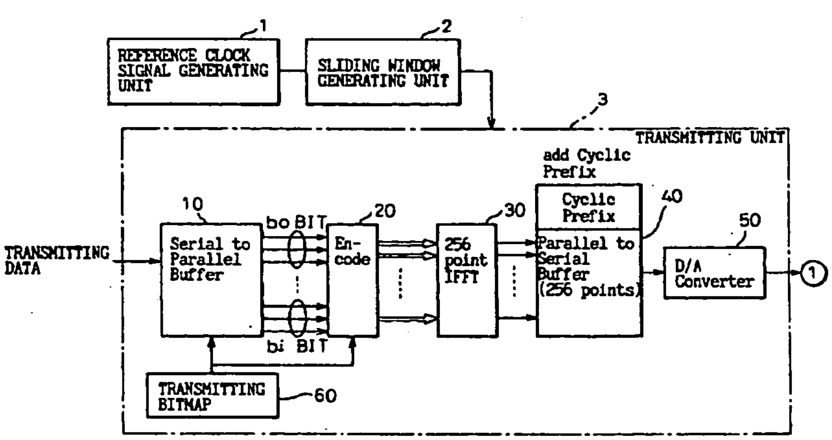
(54) **Digital subscriber line communicating system**

(57) A digital subscriber line communicating system having a central office and a remote terminal connected through a telephone line, the transmitting side comprising a sliding window transmitting unit for transmitting DMT symbols according to the sliding window through the telephone line to the receiving side, and the receiving side comprising a sliding window receiving unit for receiving DMT symbols according to the sliding window from the transmitting side, the sliding window indicating the phase of cross-talk condition due to a TCM-ISDN transmission at the receiving side, whereby TCM cross-talk can be reduced without largely departing from the standard system.

Fig.1A



EP 0 961 449 A2

Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to a digital subscriber line communicating system which utilizes an existing telephone line as a high speed data communication line. More particularly, it relates to an improvement of a modulation/demodulation system in a transmission apparatus used in the above-mentioned transmission system.

[0002] In recent years, multimedia services such as internet and so forth have expanded through the whole society including usual homes. Accompanied by such development, it has been strongly required to promptly provide an economical and reliable digital subscriber line communicating system for utilizing such services.

2. Description of the Related Art

(1) An explanation of an ADSL

[0003] As a technique to provide a subscriber line communicating system which utilizes the existing telephone line as a high speed data communication line, an xDSL (Digital Subscriber Line) is known. xDSL is a communicating system which utilizes a telephone line and a modulation/demodulation technique. xDSLs are generally classified into a symmetric type and an asymmetric type. In the symmetric type, upstream transmission speed from a subscriber home (hereinafter referred to as a remote terminal side) to an accommodating central office (hereinafter referred to as a central office side) is symmetric with the transmission speed from the central office side to the remote terminal side. In the asymmetric type, the transmission speed from the remote terminal side to the central office side is asymmetric with the transmission speed from the central office side to the remote terminal side.

[0004] In the asymmetric xDSLs, there is an Asymmetric DSL (ADSL) modem which is provided with the G.DMT standard having a downstream transmission speed of about 6 Mbit/sec. and the G.lite standard having a downstream transmission speed of about 1.5 bits/sec. Both of the G.DMT and G.lite employ Descrete Multitone (DMT) modulation.

(2) An Explanation of the DMT Modulation

[0005] DMT modulation will be explained using G.lite as an example. This explanation and the associated drawing will describe only the downstream modulation/demodulation from the central office to the remote terminal. However, DMT modulation is also possible in the upstream modulation/demodulation.

[0006] Firstly, transmitting data is input into an ADSL transceiver unit (ATU) in the central office and a non-symbol time (1/4 kHz) of the data is stored in a serial to parallel buffer. The stored data are divided into a plurality of groups. A predetermined number of transmission bits per carrier signal is previously allocated to each group in accordance with a transmitting bitmap which will be described later in detail. Each group is output to an encoder. In the encoder, each group of the input bit series is converted into a signal point expressed by a complex number for an orthogonal amplitude modulation and is output to IFFT. The IFFT performs the conversion from each of the signal points to transmit the signal sequences by an inverse fast Fourier transform. The signals from the IFFT are output to a parallel to serial buffer. Here the sixteen points of the outputs of the IFFT are added as a Cyclic Prefix to the head of each DMT symbol. The output of the parallel to serial buffer is supplied to a D/A converter in which the digital signal with a sampling frequency of 1.104 MHz is converted into an analog signal. The analog signal is transmitted through a metalic line to a remote terminal.

[0007] At the remote terminal side, the analog signal is converted into a digital signal with the sampling frequency of 1.104 MHz by an A/D converter. Each DMT symbol of the digital signal is stored in a serial to parallel buffer. In the buffer, the Cyclic Prefix is removed from the digital signal, and the remaining signal is output to an FFT. In the FFT, a fast Fourier transform is effected to generate or demodulate the signal points. The demodulated signal points are decoded by a decoder in accordance with a receiving bitmap having the same values as those in the transmitting bitmap. The decoded data are stored in a parallel to serial buffer as receiving data of bit-sequences.

(3) A Detailed Explanation of the Bitmap

[0008] The bitmap described in the explanation of the DMT will be explained in detail with reference to Figs. 13A and 13B.

[0009] The apparatus at the central office side and the apparatus at the remote terminal side both measure the ratio of the receiving signal to noise (hereinafter referred to as S/N) during a training period prior to communication to determine the number of bits to be transmitted by each modulating carrier. As shown in Figs. 13A and 13B, for a carrier signal

with a larger S/N, a larger number of bits to be transmitted are allocated; and for a carrier signal with a smaller S/N, a smaller number of bits to be transmitted are allocated.

[0010] By the above allocation, the receiving side measures the S/N to prepare the bitmap which indicates the numbers of bits to be transmitted corresponding to the carrier numbers.

[0011] The receiving side informs this bitmap to the transmitting side during a training period so that both the transmitting side and the receiving side can perform the modulation/demodulation with the use of the same bitmap during normal data communication.

(4) Countermeasure Against Cross-Talk From The Time Compression Modulation ISDN Transmission (hereinafter referred to as TCM ISDN Transmission)

[0012] When there is a cross-talk due to the TCM ISDN Transmission, in the prior art, two different bitmaps are used in the ADSL modem in the transmitting side or in the receiving side so as to improve the transmission characteristic. This method of using the two bitmaps will be explained with reference to Fig. 14.

[0013] In the TCM ISDN transmission, the central office side transmits downstream data during a prior half of one cycle of a reference clock signal of 400 Hz shown in (1) of Fig. 14, in synchronization with the reference clock signal of 400 Hz; and the remote terminal side receives the downstream data and then transmits upstream data. Therefore, the ADSL modem in the central office is influenced by a Near End Cross-Talk (hereinafter referred to as NEXT) from the ISDN during the prior half of the one cycle of 400 Hz, and is influenced by a Far End Cross-Talk (hereinafter referred to as FEXT) from the upstream data of the remote terminal side ISDN.

[0014] Contrary to the central office, the ADSL modem in the remote terminal is influenced by a FEXT during a prior half of one cycle of the reference clock signal of 400 Hz, and is influenced by a NEXT during a latter half of the cycle.

[0015] If the metalic cable between the central office and the remote terminal is long, the S/N of the receiving signal to the NEXT is made smaller, and in some cases, the NEXT may be greater than the receiving signal.

[0016] In these cases, since the influence of the FEXT is not so large, in the prior art, two bitmaps are provided. One is a bitmap (DMT symbol X) for receiving signals during the NEXT period at the remote terminal. The other is a bitmap (DMT symbol Y) for receiving signals during the FEXT period at the remote terminal. During the NEXT period, in the prior art, the number of bits to be transmitted is made small so as to improve the resistance of the signals against the S/N. During the FEXT period, in the prior art, the number of bits to be transmitted is made large so as to increase the transmission capacity.

[0017] On the other hand, the time interval of one DMT symbol is usually 246 μs with a Cyclic Prefix of 16 points. Contrary to this, in the prior art, in order to conform the one DMT symbol with the TCM Cross-talk period of 400 Hz, the time interval of one DMT symbol is made to be 250 μs with a cyclic Prefix of 20 Points so that one period of the TCM Cross-talk is made to coincide with the time period of ten DMT symbols, whereby the synchronization with the TCM Cross-talk is established.

[0018] The above-mentioned prior art method of employing the two bitmaps, however, is largely different from the standard system in which only a single bitmap is employed. If two bitmaps are employed, the sequence of informing the bitmaps obtained from the S/N during a training period from the receiving side to the transmitting side must be modified, and in addition, the informing period is doubled so that the training period is increased.

[0019] In the apparatus of the central office or the remote terminal, the memory capacity must be increased in order to store the bitmaps, so that a cost problem occurs.

[0020] Further, to change the length of the Cyclic Prefix is largely different from the specification of the standard system so that the above-mentioned countermeasure against the TCM cross-talk cannot be performed in the hardware of the apparatus employing the standard system.

SUMMARY OF THE INVENTION

[0021] An object of the present invention is to provide a digital subscriber line transmission system capable of performing a countermeasure against TCM cross-talk, without largely departing from the standard system but by modifying only a part of the hardware tinder the standard system.

[0022] Another object of the present invention is to provide a digital subscriber line transmission system which can communicate at a most suitable transmission speed, regardless of whether or not there is cross-talk.

[0023] To attain the above objects, there is provided, according to the present invention, a digital subscriber line communicating system for communicating between a transmitting side and a receiving side through a communication line, comprising: a sliding window generating unit for generating a sliding window based on a timing signal representing a periodical noise duration; and a sliding window transmitting unit for transmitting modulated symbol according to the sliding window through the communication line to the receiving side.

[0024] The periodical noise duration is caused with a cross-talk noise on the communication line from an another

transmission system using time compression modulation.

[0025] Both the sliding window generating unit and the sliding window transmitting unit are located in the transmitting side.

[0026] The sliding window is generated in such a way that inside modulated symbol of the sliding window is received by the receiving side when the receiving side is in a far end cross-talk duration.

[0027] According to an aspect of the present invention, the transmission side is a central office and the receiving side is a remote terminal. In this aspect, the central office comprises; a timing signal generating unit for generating the timing signal synchronized with the transmission system which interferes the central office and the remote terminal. The the sliding window generating unit is operatively connected to the timing signal generating unit, and the sliding window is a downstream sliding window indicating the phase of noise condition of the remote terminal. Also, the sliding window transmitting unit transmits modulated symbols according to the downstream sliding window through the communication line to the remote terminal. Further, the remote terminal comprises: a sliding window receiving unit for receiving modulated symbols according to the downstream sliding window from the central office. The downstream sliding window indicates cross-talk durations due to the TCM ISDN transmission at the remote terminal.

[0028] The downstream sliding window is generated in such a way that inside symbol of the downstream sliding window is received by the remote terminal in a first cross-talk duration determined with a far end cross-talk duration at the remote terminal.

[0029] The first cross-talk duration is within a prior half of each cycle of the timing signal, and a second cross-talk determined with a near end cross-talk duration at the remote terminal, is within a latter half of each cycle of the timing signal,

[0030] Inside of the downstream sliding window is formed within the first cross-talk duration.

[0031] During timing recover training between the central office and the remote terminal, inside symbol of the downstream sliding window is formed by a first kind of signal, and outside symbol of the downstream sliding window is formed by a second kind of signal, the first kind of signal and the second kind of signal being obtained by modulating a carrier signal but being different in phase by a predetermined angle.

[0032] When the first modulated symbol is synchronized with the head of one cycle of the timing signal, the central office comprises a duration discriminating unit for discriminating whether N-th modulated symbol belongs to inside or outside of the downstream sliding window.

[0033] The central office includes a transceiver comprising the timing signal generating unit and the sliding window generating unit.

[0034] According to another aspect of the present invention, the transmission side is a remote terminal and the receiving side is a central office. In this aspect, the remote terminal comprises; a timing signal receiving unit for receiving a timing phase via received modulated symbol according to a downstream sliding window from the central office, the timing signal being synchronized with a transmission system which interferes the central office and the remote terminal. In this aspect also, the sliding window generating unit is operatively connected to the timing signal receiving unit, and the sliding window is an upstream sliding window indicating the phase of noise condition of the central office; and a sliding window transmitting unit for transmits modulated symbols according to the upstream sliding window through the communication line to the central office. The upstream sliding window indicates a cross-talk duration due to the TCM ISDN transmission at the central office. The upstream sliding window is generated in such a way that an inside symbol of the upstream sliding window is received by the central office in a third cross-talk duration determined with a far end cross-talk duration at the central office. In an embodiment, a fourth cross-talk duration determined with a near end cross-talk duration at the central office is within a prior half of each cycle of the timing signal, and the third cross-talk duration is within a latter half of each of the timing signal, and inside of the upstream sliding window is formed within the third cross-talk duration. When the first modulated symbol is synchronized with the head of one cycle of the timing signal, the remote terminal comprises a duration discriminating unit for discriminating whether N-th modulated symbol belongs to inside or outside of the upstream sliding window.

[0035] During training between the transmitting side and the receiving side, a training sequence switching symbol is transmitted from the transmitting side in such a way that the receiving side receives the head of the training sequence switching symbol during a far end cross-talk duration.

[0036] The number of bits to be transmitted per a carrier signal corresponds to a signal to noise ratio for the carrier signal, only the modulated symbols received completely inside of a near end cross-talk duration at the receiving side being used to measure the NEXT duration S/N, and only the inside modulated symbols of the sliding window at the receiving side being used to measure the FEXT duration S/N.

[0037] The digital subscriber line communicating system further comprises a sliding window bitmap transmission system for transmitting data symbols only inside of the sliding window with transmitting capacity determined by the S/N measurement in the inside of the sliding window at the receiving side.

[0038] The digital subscriber line communicating system further comprises a standard transmission system, wherein, according to the standard transmission system, data symbols are transmitted in both inside and outside of the sliding

window with transmitting capacity determined by the S/N measurement in NEXT duration at the receiving side; and wherein the system having the larger transmitting capacity is selected to perform the communication.

[0039] The digital subscriber line communicating system comprises modified sliding window bitmap transmission system for transmitting data symbols in both inside and outside of the sliding window, and the inside data symbols are transmitted with transmitting capacity determined by the S/N measurement in the inside of the sliding window and the outside data symbols are transmitted with transmitting capacity determined by the S/N measurement in the NEXT duration at the receiving side.

[0040] According to one of the sliding window bitmap transmission system, at least a pilot tone used for synchronization of timing is transmitted outside of the sliding window.

[0041] According to one of the sliding window bitmap transmission system and the modified sliding window bitmap transmission system, a first predetermined number of super frames, each of which is composed of second predetermined number of modulated symbols and a synchronizing symbol, constitute a single unit, the single unit being synchronized with an integer multiple of one cycle duration of the timing signal, and one of the synchronizing symbols in the single unit, i.e., an inverse synchronizing symbol, is made different from other the synchronizing symbol in order to maintain the single unit to be synchronized between the central office and the remote terminal, and the inverse synchronizing symbol in N-th super frame of the super frames is received in the FEXT duration at the receiving side.

[0042] In an embodiment, the N-th super frame is 4-th super frame for downstream and first super frame for upstream, and the first predetermined number of super frames is 5, the second predetermined number of modulated symbols is 68.

[0043] According to further aspect of the present invention, there is provided a transceiver in a central office connected through a communication line to a remote terminal, the transceiver comprising: a timing signal generating unit for generating the timing signal representing a periodical noise duration; a sliding window generating unit, operatively connected to the timing signal generating unit, for generating a downstream sliding window indicating the phase of noise condition of the remote terminal; and a sliding window transmitting unit for transmitting modulated symbols according to the downstream sliding window through the communication line to the remote terminal.

[0044] The periodical noise duration is caused with a cross-talk noise on the communication line from an another transmission system using time compression modulation.

[0045] The downstream sliding window is generated in such a way that an inside symbol of the downstream sliding window is received by the remote terminal in a far end cross-talk duration at the remote terminal i.e., R-FEXT duration.

[0046] The first cross-talk duration is within a prior half of each cycle of the timing signal, and a second cross-talk duration determined with a near end cross-talk duration at the remote terminal is within a latter half of each cycle of the timing signal, inside of the downstream sliding window being formed within the first cross-talk duration.

[0047] During timing recover training between the central office and the remote terminal, inside symbol of the downstream sliding window is formed by a first kind of signal, and outside symbol of the downstream sliding window is formed by a second kind of signal, the first kind of signal and the second kind of signal being obtained by modulating a carrier signal but being different in phase by a predetermined angle.

[0048] When the first modulated symbol is synchronized with the head of one cycle of the timing signal, the central office comprises a duration discriminating unit for discriminating whether N-th modulated symbol belongs to inside or outside of the downstream sliding window.

[0049] According to still further aspect of the present invention, there is provided a transceiver in a remote terminal connected through a communication line to a central office, the transceiver comprising: a timing signal receiving unit for receiving a timing phase via received modulated symbol according to a downstream sliding window from the central office, the timing signal being synchronized with a transmission system using time compression modulation which interferes the central office and the remote terminal; a sliding window generating unit, operatively connected to the timing signal receiving unit, for generating an upstream sliding window indicating the phase of noise condition of the central office; and a sliding window transmitting unit for transmitting modulated symbols according to the upstream sliding window through the communication line to the central office; the upstream sliding window indicating cross-talk duration due to the TCM ISDN transmission at the central office.

[0050] The upstream sliding window is generated in such a way that inside symbol of the upstream sliding window is received by the central office in a far end cross-talk duration at the central office i.e., C-FEXT duration.

[0051] A near end cross-talk duration at the central office, i.e., C-NEXT duration, is within a prior half of each cycle of the timing signal, and the third cross-talk duration is within a latter half of each of the timing signal, inside of the upstream sliding window being formed within the third cross-talk duration.

[0052] When the first modulated symbol is synchronized with the head of one cycle of the timing signal, the remote terminal comprises a duration discriminating unit for discriminating whether N-th modulated symbol belongs to inside or outside of the upstream sliding window.

BRIEF DESCRIPTION OF THE DRAWINGS

[0053] The above objects and features of the present invention will be more apparent from the following description of the preferred embodiments with reference to the accompanying drawings, wherein:

Fig. 1A is a block diagram showing a central office according to an embodiment of the present invention;
Fig. 1B is a block diagram showing a remote terminal according to an embodiment of the present invention;
Fig. 2, is a diagram showing a method for transmitting synchronization signals according to an embodiment of the present invention;
Fig. 3 is a diagram showing how to define noise durations during an initial training period according to an embodiment of the present invention;
Fig. 4 is a timing chart of transmitting a sequence switching symbol according to an embodiment of the present invention;
Fig. 5 is a diagram showing how to define noise durations in receiving symbols during measuring an S/N, according to an embodiment of the present invention;
Fig. 6 is a block diagram of an embodiment for measuring the S/N in each of the NEXT or FEXT duration, according to an embodiment of the present invention;
Fig. 7 is a graph showing transmitting capacities according to the standard method and the SWB method of the present invention;
Fig. 8 is a diagram showing bitmaps according to the standard method and the SWB method;
Fig. 9 is a diagram showing a transmission pattern from the central office according to the SWB method;
Fig. 10 is a diagram showing a transmission pattern from the remote terminal according to the SWB method;
Fig. 11 is a diagram showing how to define the noise durations during communication;
Fig. 12 is a diagram showing the SWB method when two bitmaps are employed;
Figs. 13A and 13B show how to define the diagram showing number of bits to be transmitted to obtain a bitmap;
Fig. 14 is a diagram showing a prior art; and
Fig. 15 is a diagram showing a transmitting pattern of each DMT symbol to inform the phase of the reference clock during timing recovery training sequence.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0054] The embodiments of the present invention will be described in the following with reference to the drawings.

[0055] Fig. 1A is a block diagram showing functional blocks of a central office according to an embodiment of the present invention; and Fig. 1B is a block diagram showing functional blocks of a remote terminal according to an embodiment of the present invention.

[0056] As shown in Fig. 1A, the central office includes a reference clock signal generating unit 1, a sliding window generating unit 2, and a sliding window transmitting unit 3. The reference signal generating unit 1 generates a reference clock signal having a frequency of, for example, 400 Hz, synchronized with a TCM ISDN transmission which interferes the central office and the remote terminal. The reference clock signal may be generated based on an external signal or within an internal signal generated by a crystal oscillator as an example.

[0057] The sliding window generating unit 2 generates a downstream sliding window from the generated reference clock signal. The downstream sliding window discriminates whether the transmitting DMT symbols are received in a far end cross-talk duration or in the other duration at the remote terminal.

[0058] The sliding window transmitting unit 3 transmits the DMT symbols according to the downstream sliding window to the remote terminal.

[0059] As shown in Fig. 1B, the remote terminal includes a sliding window receiving unit 4, a reference clock signal generating unit 5, and a sliding window generating unit 6.

[0060] The sliding window receiving unit 4 receives the DMT symbol according to the downstream sliding window from the central office.

[0061] The reference clock signal generating unit 5 generates a reference clock signal based on the reference clock signal generated by the reference clock signal generating unit 1 in the central office, and transmitted from the central office to the remote terminal.

[0062] The sliding window generating unit 6 generates an upstream sliding window from the generated reference clock signal by the reference clock signal generating unit 5. The generated downstream sliding window discriminates whether the received DMT symbols are received in a far end cross-talk duration or other duration at the remote terminal.

[0063] The reference clock signal in the central office or in the remote terminal may be generally referred to as a timing signal which is synchronized with the transmission system which interferes the central office and the remote terminal.

[0064] The DMT modulation will be explained using the G.lite as an example, with reference to Figs. 1A and 1B. This

explanation and the associated drawing will describe only the downstream modulation/demodulation from the central office to the remote terminal. However, the DMT modulation is also possible in the upstream modulation/demodulation.

[0065] Firstly, transmitting data is input into an ADSL transceiver unit (ATU) in the central office and a non-symbol time (1/4 kHz) of the data is stored in a serial to parallel buffer 10. The stored data are divided into a plurality of groups. A predetermined number of transmission bits b0, ..., or bi per a carrier signal is previously allocated to each group in accordance with a transmitting bitmap 60 which will be described later in detail. Each group is output to an encoder 20. In the encoder 20, each group of the input bit series is converted into a signal point expressed by a complex number for an orthogonal amplitude modulation and is output to IFFT 30. The IFFT 30 performs the conversion from each of the signal points to transmit signal sequence by an inverse fast Fourier transform. The signals from the IFFT 30 are output to a parallel to serial buffer 40. Here the sixteen tail points 240 - 255 of the outputs of the IFFT 30 are added as a Cyclic Prefix to the head of each DMT symbol. The output of the parallel to serial buffer 40 is supplied to a D/A converter 50 in which the digital signal with a sampling frequency of 1.104 MHz is converted into an analog signal. The analog signal is transmitted through a metalic line 100 to a remote terminal.

[0066] At the remote terminal side, the analog signal is converted into a digital signal with the sampling frequency of 1.104 MHz by an A/D converter 110. Each DMT. symbol of the digital signal is stored in a serial to parallel buffer 120. In the buffer 120, the Cyclic Prefix is removed from the digital signal, and the remaining signal is output to an FFT 130. In the FFT 130, a fast Fourier transform is effected to generate or demodulate the signal points. The demodulated signal points are decoded by a decoder 140 in accordance with a receiving bitmap 160 having the same values as those in the transmitting bitmap 60. The decoded data are stored in a parallel to serial buffer 150 as receiving data of bit-sequences b0, and bi.

[0067] Figure 2 is a diagram showing a method for transmitting synchronization signals according to an embodiment of the present invention. In Fig. 2, (1) represents a reference clock signal for transmitting a Time Compression Modulation (TCM) signal having a frequency of 400 Hz between the central office to the remote terminal; (2) represents NEXT durations, i.e., C-NEXT durations and FEXT durations, i.e., C-FEXT durations at the central office which are synchronized with the reference clock signal (1) of 400 Hz; (3) represents FEXT durations, i.e., R-NEXT durations and NEXT durations, i.e., R-NEXT durations at the remote terminal which are synchronized with the reference clock signal (1) of 400 Hz;(4) represents symbols A and B transmitted from the central office to the remote terminal during an initial training; and (5) represents symbols A and B received by the remote terminal. The time difference between (4) and (5) is the propagation delay. Each of the symbols A and B has a duration of 256 samples. The symbols A and B are used to inform the NEXT duration and the FEXT duration from the central office to the remote terminal.

[0068] The symbols A and B are signals obtained by selecting a carrier having a relatively low frequency at which TCM cross-talk is small; modulating the selected carrier by the 4-value QAM as an example to obtain 4 signal points; and selecting two signal points A and B from the 4 signal points. The phases of the two signal points A and B are different by 90° to each other. The selected signal points A and B are shown in Fig. 15, as an example. The two signal points are converted by the IFFT 30 from the frequency domain to the time domain.

[0069] At the remote terminal, it is impossible to discriminate each boundary of DMT symbols output from the IFFT 30 in the central office. Therefore, it is impossible to coincide an FFT interval with a DMT symbol interval, so that signal points after modulation do not appear in correct phases or quadrants. However, by employing the two symbols A and B having phases different by 90° to each other, the modulated two symbols also have phases different by 90° to each other so that, even when there is an error in phase of the modulated signal points, the remote terminal can discriminate its NEXT duration, i.e., R-NEXT duration from its FEXT duration, i.e., R-FEXT duration.

[0070] Figure 3 shows how to define the R-NEXT duration and the R-FEXT duration when a signal having a frequency of 400 Hz is transmitted during an initial training.

[0071] At the central office, once an ADSL modem detects the phase of the reference clock signal having the frequency of 400 Hz, a DMT symbol counter for counting each sample and a counter for discriminating the NEXT duration and the FEXT duration at the central office, i.e., the C-NEXT duration and the C-FEXT duration, are started, whereby it becomes possible to discriminate whether a received DMT symbol belongs to the C-NEXT duration or the C-FEXT duration without generating the reference clock signal from the received DMT symbols.

[0072] In Fig. 3, (1) shows counter values "a", "b", and "c", The counter value "a" represents the FEXT duration at the remote terminal; the counter value "b" represents the NEXT duration at the remote terminal; and the counter value "c" represents the remaining period obtained by subtracting (a + b) from one cycle period of the reference clock signal. These values are determined by taking a round trip delay generated by a propagation delay in the TCM ISDN transmission, (2) in Fig. 3 shows the case when all of the received DMT symbols are included in the R-FEXT duration at the remote terminal; and (3) in Fig. 3 shows the case when a part of the received DMT symbols are included in the R-NEXT duration at the remote terminal.

[0073] When the first DMT symbol is synchronized with the head of one cycle of the reference clock signal of 400 Hz as shown in (2) of Fig. 3, the determination of whether n-th DMT symbol belongs to the R-FEXT duration or the R-NEXT duration can be performed as follows.

[0074] It is assumed that there are 2760 samples in one cycle of the reference clock signal of 400 Hz, as shown in (1) of Fig. 3. Also, each symbol is assumed to have 256 samples during training as shown in (2) of Fig. 3. Then, a parameter S is defined as:

$$S = \{256 * (n - 1)\}\mathrm{mod}2760.$$

[0075] If {(S < (a - 256)} or {S > (a + b)} is satisfied, then it is judged that the n-th symbol belongs to an R-FEXT duration.

[0076] If {(a - 256) ≦ S ≦ (a + b)} is satisfied, then it is judged that the n-th symbol belongs to an R-NEXT duration.

[0077] From an ADSL modem in the central office, a sequence switching symbol is transmitted to inform the switching timing of the training sequence to the opposite party. If the receiving side cannot recognize the head of the sequence switching symbol, it is impossible to normally perform the training. In order to surely inform the sequence switching, the sequence switching symbol is transmitted at a time when the receiving side can receive the head of the sequence switching symbol during a FEXT duration according to an embodiment of the present invention at the receiving side.

[0078] Fig. 4 shows the timing of the sequence switching symbol informed from the central office to the remote terminal. In Fig. 4, (1) represents the reference clock signal of 400 Hz; (2) shows the C-NEXT durations and C-FEXT durations at the central office; (3) shows the head of the sequence switching symbol transmitted from the central office; (4) shows the head of the sequence switching symbol received by the remote terminal; and (5) shows the R-FEXT durations and R-NEXT durations at the remote terminal. The slashed portions in the figure represent the head of the sequence switching symbol. As shown in (3) and (4) of Fig. 4, the head of the sequence switching symbol is received during the R-FEXT duration at the remote terminal.

[0079] In the ADSL modem also, during training, a signal to noise S/N is measured for each modulating carrier in the receiving signal to determine the number of bits to be transmitted for each modulating carrier. Under the TCM cross-talk environment, the S/N measurement must be performed in each of the NEXT durations and the FEXT durations by taking the influence of the NEXT or the FEXT into account.

[0080] Fig. 5 shows how to define the NEXT duration and the FEXT duration for measuring the S/N. In Fig. 5, (1) shows the reference clock signal of 400 Hz; (2) shows the original R-FEXT duration and the original R-NEXT duration at the remote terminal when S/N is not measured; (3) shows the definition of an R-FEXT duration "a" for measuring S/N and of an R-NEXT duration "e" for measuring S/N; (4) shows DMT symbols in the FEXT duration "a"; and (5) shows DMT symbols in the R-NEXT duration "e". As shown in Fig. 5, the R-NEXT duration "a" for measuring S/N and the R-FEXT duration "e" for measuring S/N are defined within the original R-FEXT duration and the original R-NEXT duration, respectively. The number of bit calculated from S/N measured in the NEXT duration must be a value which can ensure a predetermined bit error rate (hereinafter referred to as BER). To this end, as shown in (4) of Fig. 5, only the DMT symbols within the R-FEXT duration "a" are used to measure the S/N in the R-FEXT duration; and as shown in (5) of Fig. 5, only the DMT symbols within the R-NEXT duration "e" are used to measure the S/N in the R-NEXT duration. The DMT symbols which are not included in either the R-FEXT duration "a" or R-NEXT duration "e" are not used to measure the S/N because they have no meaning as information to determine the number of bits to be transmitted.

[0081] When the first symbol of the DMT symbols is synchronized with the head of the cycle of the receiving signal of 400 Hz, the determination of whether the n-th symbol belongs to the FEXT duration for measuring S/N or the NEXT duration for measuring S/N can be performed as follows.

[0082] It is assumed that there are 2760 samples in one cycle of the reference signal of 400 Hz, as shown in (1) of Fig. 5. Also, each symbol is assumed to have 272 samples during communication, as shown in (4) of Fig. 5. Then, a parameter S is defined as:

$$S = \{272 * (n - 1)\}\mathrm{mod}2760.$$

[0083] If {(S < (a - 272)} or {S > (a + d ± e + f)} is satisfied, then it is judged that the n-th symbol belongs to an R-FEXT duration for measuring S/N.

[0084] If {(a + d) < S < (a + d + e - 272)} is satisfied, then it is judged that the n-th symbol belongs to an R-NEXT duration for measuring S/N.

[0085] If any one of the above conditions is not satisfied, then the n-th symbol is not considered for measuring S/N.

[0086] If should be noted that (d + e + f) is equal to "b" in Fig. 3 or in Fig. 11.

[0087] Fig. 6 is a block diagram of an S/N measuring unit in the ADSL modem in the remote terminal.

[0088] When a demodulator 210 receives receiving data, it outputs signal points of each carrier signal as demodulated data. A reference unit 220 outputs signal points of respective carrier signals which are to be received when there is no error. The difference between a signal point from the reference unit 220 and a corresponding demodulated signal point from the demodulator 210 is an ERROR. The ERROR is input to a selector 260.

[0089] Further, a clock signal generated from a clock generator 230 in the remote terminal is divided by a frequency

divider 240 into a signal having a frequency of 400 Hz. The phase of the signal of 400 Hz generated by the frequency divider 240 is synchronized with the phase of the signal of 400 Hz transmitted from the central office. The signal of 400 Hz from the frequency divider 240 is input to a phase discriminator 250. The phase discriminator 250 judges, based on the signal of 400 Hz input into the phase discriminator 250, that the received DMT symbol belongs to a FEXT duration, a NEXT duration, or other duration. The judged result is input to a selector 260. The selector 260 transfers the above-mentioned ERROR to a NEXT duration S/N measuring unit 270 or a FEXT duration S/N measuring unit 280, in accordance with the judged result from the phase discriminator 250. Each of the S/N measuring units integrates the ERRORs to calculate S/N. The S/N for each carrier signal is output to a transmitting capacity calculating unit 290. The transmitting capacity calculating unit 290 calculates the number of bits to be transmitted for each carrier signal, based on the S/N of each carrier signal, to output a bitmap b-NEXT for a NEXT duration and a bitmap b-FEXT for a FEXT duration.

[0090] The ADSL modem in the remote terminal calculates a transmitting capacity based on the b-NEXT and the b-FEXT. That is, based on the fact that the value in the b-FEXT duration is the number of bits to be transmitted which can be received during R-FEXT durations only, and the value in the b-NEXT duration is the number of bits to be transmitted which can be received in all durations, the following two values are obtained;

$$\text{a transmitting capacity 1} = (\text{b- total bit number in FEXT}) \times \alpha \times \text{modulation rate; and}$$

$$\text{a transmitting capacity 2} = (\text{b- total bit number in NEXT}) \times 1.0 \times \text{modulation rate.}$$

[0091] Then the larger transmitting capacity is selected by communication between the central office and the remote terminal.

[0092] Here the method to transmit data in all durations by using the bitmap b-NEXT is referred to as the standard method; and the method to transmit data only during R-FEXT durations is referred to as sliding window bitmap (hereinafter referred to as SWB) method.

[0093] Fig. 7 is a graph showing the transmitting capacity in the standard method and in the SWB method. The solid curve in the figure represent the standard method; and the dashed curve represents the SWB method. As shown in Fig. 7, under an environment where there is a TCM cross-talk, when the standard method is employed, the longer the length of the line becomes, the larger the influence of the NEXT; in contrast, when the SWB method is employed, even though the transmitting capacity is not high when the line is short, the transmitting capacity is not largely lowered even when the length of the line becomes large.

[0094] When the line length is L, the transmitting capacity according to the standard method is the same as the transmitting capacity according to the SWB method. Therefore, it is preferable to select the standard method when the line length is shorter than the length L, and to select the SWB method when the line length is longer than the length L.

[0095] Fig. 8 shows a transmitting DMT symbols according to the standard method and the SWB method. In Fig. 8, (1) shows the reference signal of 400 Hz; (2) shows the NEXT durations and FEXT durations at the central office; (3) shows DMT symbols transmitted from the central office according to the standard method; (4) shows DTM symbols X obtained by the b-NEXT bitmap; and (5) shows DMT symbols Y obtained by the b-FEXT bitmap.

[0096] According to the SWB method, the transmitting side slides the window so as to allocate transmitting bits to each carrier signal only when the transmitting side is in the C-NEXT durations, that is, only when the receiving side is in the R-FEXT durations, and the receiving side slides the window to demodulate the received data during the R-FEXT durations, as shown in (5) of rig. 8.

[0097] Further, the transmitting signal of a DMT symbol outside the sliding window may be a pilot tone for a timing synchronization, and the other carrier signal may be any signal.

[0098] Fig. 9 shows a transmitting signal pattern transmitted from the central office according to the SWB method.

[0099] In Fig. 9, (1) shows the reference clock signal of 400 Hz; (2) shows the FEXT durations and the NEXT durations at the remote terminal; and (3) shows the transmitting signal pattern transmitted from the central office.

[0100] The ADSL modern in the central office generates one super frame by 69 DMT symbols. In the 69-th DMT symbol, a synchronizing symbol S indicating the boundary of the super frame is inserted. The synchronizing symbol S does not include user data. The ADSL modem transmits the above-mentioned super frames.

[0101] According to the SWB method, five super frames form a single unit. The time duration of the single unit is made to coincide with an integer multiple of the time duration (2.5 ms) of one cycle of the reference clock signal of 400 Hz shown in (1). In order to allow the remote terminal to recognize the fifth super frame as a boundary of the super frames, the fourth synchronizing symbol S is inverted in the central office to be an inverted synchronizing symbol I. Thus the signal point of the inverted synchronizing signal I is different by 180° from the signal point of the synchronizing signal S. By sending the inverted synchronizing signal I in the position of the fourth synchronizing symbol, the remote terminal can receive this inverted synchronizing signal I in an R-FEXT duration so that the remote terminal can surely establish a synchronization of its own SWB with the SWB of the central office.

[0102] Fig. 10 shows a transmitting signal pattern transmitted from the remote terminal according to the SWB method.

[0103] In Fig. 10, (1) shows the reference signal of 400 Hz; (2) shows the NEXT durations and the FEXT durations at the central office; and (3) shows the transmitting signal pattern transmitted from the remote terminal.

[0104] The transmitting signal pattern transmitted from the remote terminal is similar to that transmitted from the central office. That is, sliding windows are formed to allow the central office to receive signals during its FEXT durations. Similar to the central office, the remote terminal also generate a single unit consisting of five super frames. In order to allow the central office to recognize the boundary of the five super frames, the first synchronizing symbol is inverted in the remote terminal to be an inverted synchronizing symbol I. Thus the signal point of the inverted synchronizing signal I is different by 180° from the signal point of the synchronizing signal S. By sending the inverted synchronizing signal I in the position of the first synchronizing symbol, the central office can receive this inverted synchronizing signal I in a FEXT duration so that the central office can detect that the remote terminal is correctly in synchronization according to the SWB method.

[0105] Fig. 11 shows how to define the R-NEXT duration and the R-FEXT duration when a signal of 400 Hz is transmitted during data communication.

[0106] During data communication, when all of the samples in a DMT symbol other than the Cyclic Prefix are within an FEXT duration, the DMT symbol is defined as the DMT symbol in the R-FEXT duration. In the other cases, the DMT symbol is defined as a DMT symbol in an R-NEXT duration. The defined durations include the round trip delay mentioned before and a system margin.

[0107] When the first DMT symbol is synchronized with the head of one cycle of the reference signal of 400 Hz, the determination of whether n-th symbol belongs to the R-FEXT duration or the R-NEXT duration can be performed as follows.

[0108] It is assumed that there are 2760 samples in one cycle of the reference clock signal of 400 Hz, as shown in (1) of Fig. 11. Also, each symbol is assumed to have 272 samples during communication, as shown in (3) of Fig. 11. Then a parameter S is defined as;

$$S = \{272 * (n - 1)\} \mathrm{mod} 2760.$$

[0109] If $\{S < (a - 272)\}$ or $\{S + 16 > (a + b)\}$ is satisfied, then it is judged that the n-th symbol belongs to a FEXT duration (B duration).

[0110] If $\{(a - 272) \leqq S\}$ and $(S + 16 \leqq (a + b)\}$ are satisfied, then it is judged that the n-th symbol belongs to an R-NEXT duration (A duration).

[0111] Fig. 12 is a diagram showing a method for modified sliding window transmission system according to an embodiment of the present invention. As shown in Fig. 12, two DMT symbols X as outside of sliding window and Y as inside of sliding window according to two bitmaps are employed. The DMT symbols X according to the first bitmap is used in the R-NEXT durations. The DMT symbols Y according to the second bitmap is used in the R-FEXT durations.

Claims

1. A digital subscriber line communicating system for communicating between a transmitting side and a receiving side through a communication line, comprising;

   a sliding window generating unit for generating a sliding window based on a timing signal representing a periodical noise duration; and
   a sliding window transmitting unit for transmitting modulated symbol according to said sliding window through said communication line to said receiving side.

2. The digital subscriber line communicating system according to claim 1, wherein said periodical noise duration is caused with a cross-talk noise on said communication line from an another transmission system using time compression modulation.

3. The digital subscriber line communicating system according to claim 1, wherein both said sliding window generating unit and said sliding window transmitting unit are located in said transmitting side.

4. The digital subscriber line communicating system according to claim 1, wherein said sliding window is generated in such a way that inside modulated symbol of said sliding window is received by said receiving side when said receiving side is in a far end cross-talk duration.

5. The digital subscriber line communicating system according to claim 1, wherein said transmission side is a central office and said receiving side is a remote terminal;

said central office comprising:

a timing signal generating unit for generating said timing signal synchronized with said transmission system which interferes said central office and said remote terminal;

said sliding window generating unit being operatively connected to said timing signal generating unit, and said sliding window being a downstream sliding window indicating the phase of noise condition of said remote terminal; and

said sliding window transmitting unit transmitting modulated symbols according to said downstream sliding window through said communication line to said remote terminal; and

said remote terminal comprising:

a sliding window receiving unit for receiving modulated symbols according to said downstream sliding window from said central office;

said downstream sliding window indicating cross-talk durations due to said TCM ISDN transmission at the remote terminal.

6. The digital subscriber line communicating system according to claim 5, wherein said downstream sliding window is generated in such a way that inside symbol of said downstream sliding window is received by said remote terminal in a first cross-talk duration determined with a far end cross-talk duration at said remote terminal.

7. The digital subscriber line communicating system according to claim 5, wherein said first cross-talk duration is within a prior half of each cycle of said timing signal, and a second cross-talk determined with a near end cross-talk duration at the remote terminal, is within a latter half of each cycle of said timing signal,

inside of said downstream sliding window being formed within said first cross-talk duration.

8. The digital subscriber line communicating system according to claim 7, wherein, during timing recover training between said central office and said remote terminal, inside symbol of said downstream sliding window is formed by a first kind of signal, and outside symbol of said downstream sliding window is formed by a second kind of signal, said first kind of signal and said second kind of signal being obtained by modulating a carrier signal but being different in phase by a predetermined angle.

9. The digital subscriber line communicating system according to claim 6, wherein when the first modulated symbol is synchronized with the head of one cycle of said timing signal, said central office comprises a duration discriminating unit for discriminating whether N-th modulated symbol belongs to inside or outside of said downstream sliding window.

10. The digital subscriber line communicating system according to claim 5, wherein said central office includes a transceiver comprising said timing signal generating unit and said sliding window generating unit.

11. The digital subscriber line communicating system according to claim 1, wherein said transmission side is a remote terminal and said receiving side is a central office, said remote terminal comprising:

a timing signal receiving unit for receiving a timing phase via received modulated symbol according to a downstream sliding window from said central office, said timing signal being synchronized with a transmission system which interferes said central office and said remote terminal;

said sliding window generating unit being operatively connected to said timing signal receiving unit, and said sliding window being an upstream sliding window indicating the phase of noise condition of said central office; and

a sliding window transmitting unit for transmitting modulated symbols according to said upstream sliding window through said communication line to said central office;

said upstream sliding window indicating a cross-talk duration due to said TCM ISDN transmission at said central office.

12. The digital subscriber line communicating system of claim 11, wherein said upstream sliding window is generated in such a way that an inside symbol of said upstream sliding window is received by said central office in a third cross-talk duration determined with a far end cross-talk duration at said central office.

13. The digital subscriber line communicating system according to claim 12, wherein a fourth cross-talk duration determined with a near end cross-talk duration at the central office is within a prior half of each cycle of said timing signal,

and said third cross-talk duration is within a latter half of each of said timing signal,

inside of said upstream sliding window being formed within said third cross-talk duration.

14. The digital subscriber line communicating system according to claim 12, wherein when the first modulated symbol is synchronized with the head of one cycle of said timing signal, said remote terminal comprises a duration discriminating unit for discriminating whether N-th modulated symbol belongs to inside or outside of said upstream sliding window.

15. The digital subscriber line communicating system according to claim 1, wherein, during training between said transmitting side and said receiving side, a training sequence switching symbol is transmitted from the transmitting side in such a way that the receiving side receives the head of said training sequence switching symbol during a far end cross-talk duration.

16. The digital subscriber line communicating system according to claim 1, wherein the number of bits to be transmitted per a carrier signal corresponds to a signal to noise ratio for said carrier signal, only the modulated symbols received completely inside of a near end cross-talk duration at the receiving side being used to measure the NEXT duration S/N, and only the inside modulated symbols of the sliding window at the receiving side being used to measure the FEXT duration S/N.

17. The digital subscriber line communicating system according to claim 16, further comprising a sliding window bitmap transmission system for transmitting data symbols only inside of said sliding window with transmitting capacity determined by the S/N measurement in the inside of said sliding window at the receiving side.

18. The digital subscriber line communicating system according to claim 17, further comprising a standard transmission system, wherein, according to said standard transmission system, data symbols are transmitted in both inside and outside of said sliding window with transmitting capacity determined by the S/N measurement in NEXT duration at the receiving side; and

wherein the system having the larger transmitting capacity is selected to perform the communication.

19. The digital subscriber line communicating system according to claim 16, comprising modified sliding window bitmap transmission system for transmitting data symbols in both inside and outside of said sliding window, and the inside data symbols are transmitted with transmitting capacity determined by the S/N measurement in the inside of said sliding window and the outside data symbols are transmitted with transmitting capacity determined by the S/N measurement in the NEXT duration at the receiving side.

20. The digital subscriber line communicating system according to claim 17 or 18, wherein, according to one of said sliding window bitmap transmission system, at least a pilot tone used for synchronization of timing is transmitted outside of said sliding window.

21. The digital subscriber line communicating system according to any one of claims 17 to 19, wherein, according to one of said sliding window bitmap transmission system and said modified sliding window bitmap transmission system, a first predetermined number of super frames, each of which is composed of second predetermined number of modulated symbols and a synchronizing symbol, constitute a single unit, said single unit being synchronized with an integer multiple of one cycle duration of said timing signal, and one of said synchronizing symbols in said single unit, i.e., an inverse synchronizing symbol, is made different from other said synchronizing symbol in order to maintain said single unit to be synchronized between said central office and

said remote terminal, and said inverse synchronizing symbol in N-th super frame of said super frames is received in the FEXT duration at the receiving side.

22. The digital subscriber line communicating system according to claim 21, wherein, said N-th super frame is 4-th super frame for downstream and first super frame for upstream, and said first predetermined number of super frames is 5, said second predetermined number of modulated symbols is 68.

23. A transceiver in a central office connected through a communication line to a remote terminal, said transceiver comprising;

a timing signal generating unit for generating said timing signal representing a periodical noise duration;
a sliding window generating unit, operatively connected to said timing signal generating unit, for generating a downstream sliding window indicating the phase of noise condition of said remote terminal; and
a sliding window transmitting unit for transmitting modulated symbols according to said downstream sliding window through said communication line to said remote terminal.

24. The transceiver according to claim 23, wherein said periodical noise duration is caused with a cross-talk noise on said communication line from an another transmission system using time compression modulation.

25. The transceiver according to claim 23, wherein said downstream sliding window is generated in such a way that an inside symbol of said downstream sliding window is received by said remote terminal in a far end cross-talk duration at said remote terminal i.e.₁ R-FEXT duration.

26. The transceiver according to claim 25, wherein said first cross-talk duration is within a prior half of each cycle of said timing signal, and a second cross-talk duration determined with a near end cross-talk duration at the remote terminal is within a latter half of each cycle of said timing signal,

inside of said downstream sliding window being formed within said first cross-talk duration.

27. The transceiver according to claim 26, wherein, during timing recover training between said central office and said remote terminal, inside symbol of said downstream sliding window is formed by a first kind of signal, and outside symbol of said downstream sliding window is formed by a second kind of signal, said first kind of signal and said second kind of signal being obtained by modulating a carrier signal but being different in phase by a predetermined angle.

28. The transceiver according to claim 25, wherein when the first modulated symbol is synchronized with the head of one cycle of said timing signal, said central office comprises a duration discriminating unit for discriminating whether N-th modulated symbol belongs to inside or outside of said downstream sliding window.

29. A transceiver in a remote terminal connected through a communication line to a central office, said transceiver comprising:

a timing signal receiving unit for receiving a timing phase via received modulated symbol according to a downstream sliding window from said central office, said timing signal being synchronized with a transmission system using time compression modulation which interferes said central office and said remote terminal;
a sliding window generating unit, operatively connected to said timing signal receiving unit, for generating an upstream sliding window indicating the phase of noise condition of said central office; and
a sliding window transmitting unit for transmitting modulated symbols according to said upstream sliding window through said communication line to said central office;
said upstream sliding window indicating cross-talk duration due to said TCM ISDN transmission at said central office.

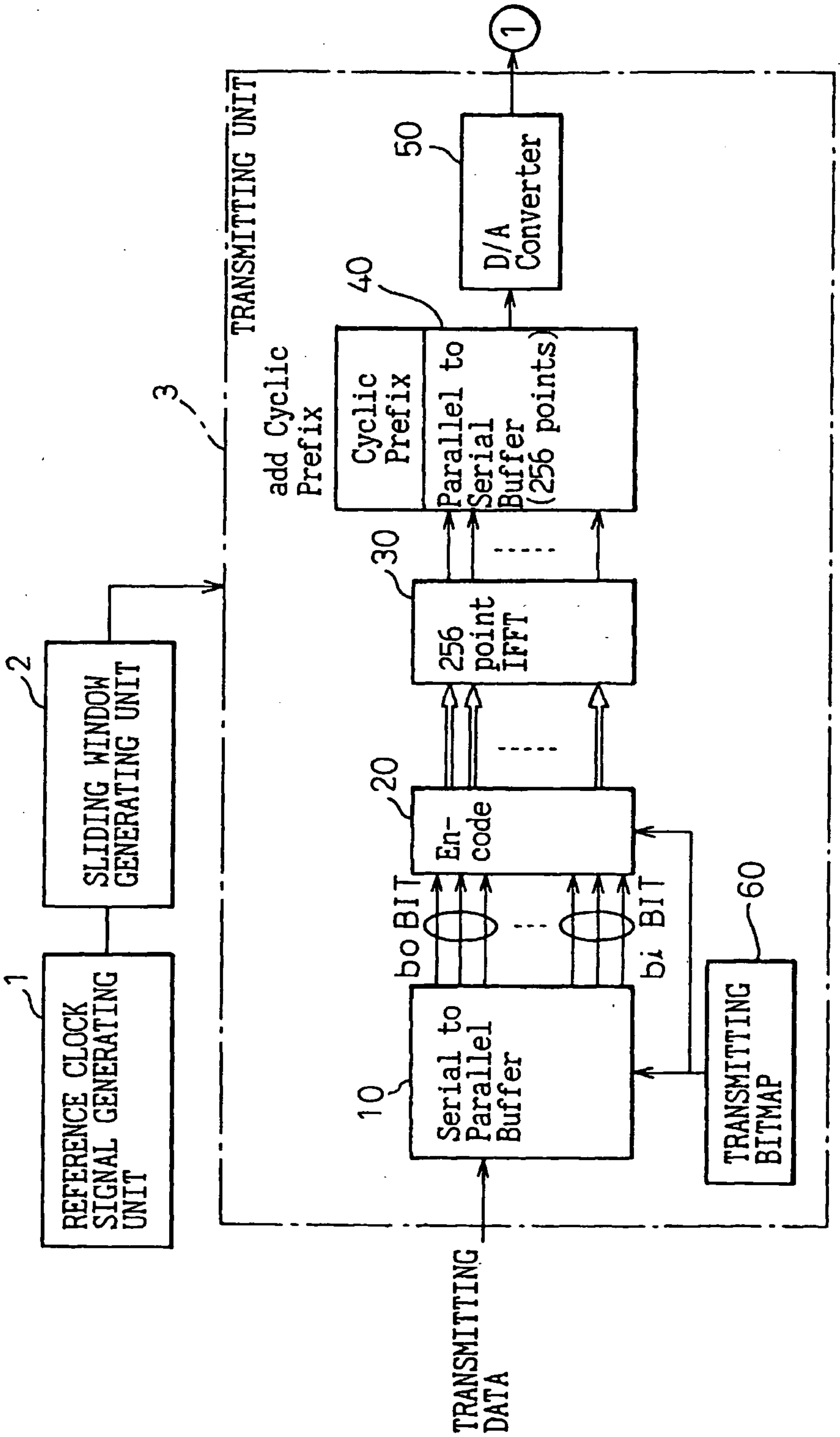
30. The transceiver according to claim 29, wherein said upstream sliding window is generated in such a way that inside symbol of said upstream sliding window is received by said central office in a far end cross-talk duration at said central office i.e., C-FEXT duration.

31. The transceiver according to claim 30, wherein a near end cross-talk duration at the central office, i.e., C-NEXT duration, is within a prior half of each cycle of said timing signal, and said third cross-talk duration is within a latter half of each of said timing signal,

inside of said upstream sliding window being formed within said third cross-talk duration.

32. The transceiver according to claim 30, wherein when the first modulated symbol is synchronized with the head of one cycle of said timing signal, said remote terminal comprises a duration discriminating unit for discriminating whether N-th modulated symbol belongs to inside or outside of said upstream sliding window.

Fig.1A



REFERENCE CLOCK SIGNAL GENERATING UNIT
1
SLIDING WINDOW GENERATING UNIT
2
3
TRANSMITTING UNIT
TRANSMITTING DATA
Serial to Parallel Buffer
10
bo BIT
bi BIT
En-code
20
256 point IFFT
30
add Cyclic Prefix
Cyclic Prefix
Parallel to Serial Buffer (256 points)
40
D/A Converter
50
1
TRANSMITTING BITMAP
60

Fig.1B

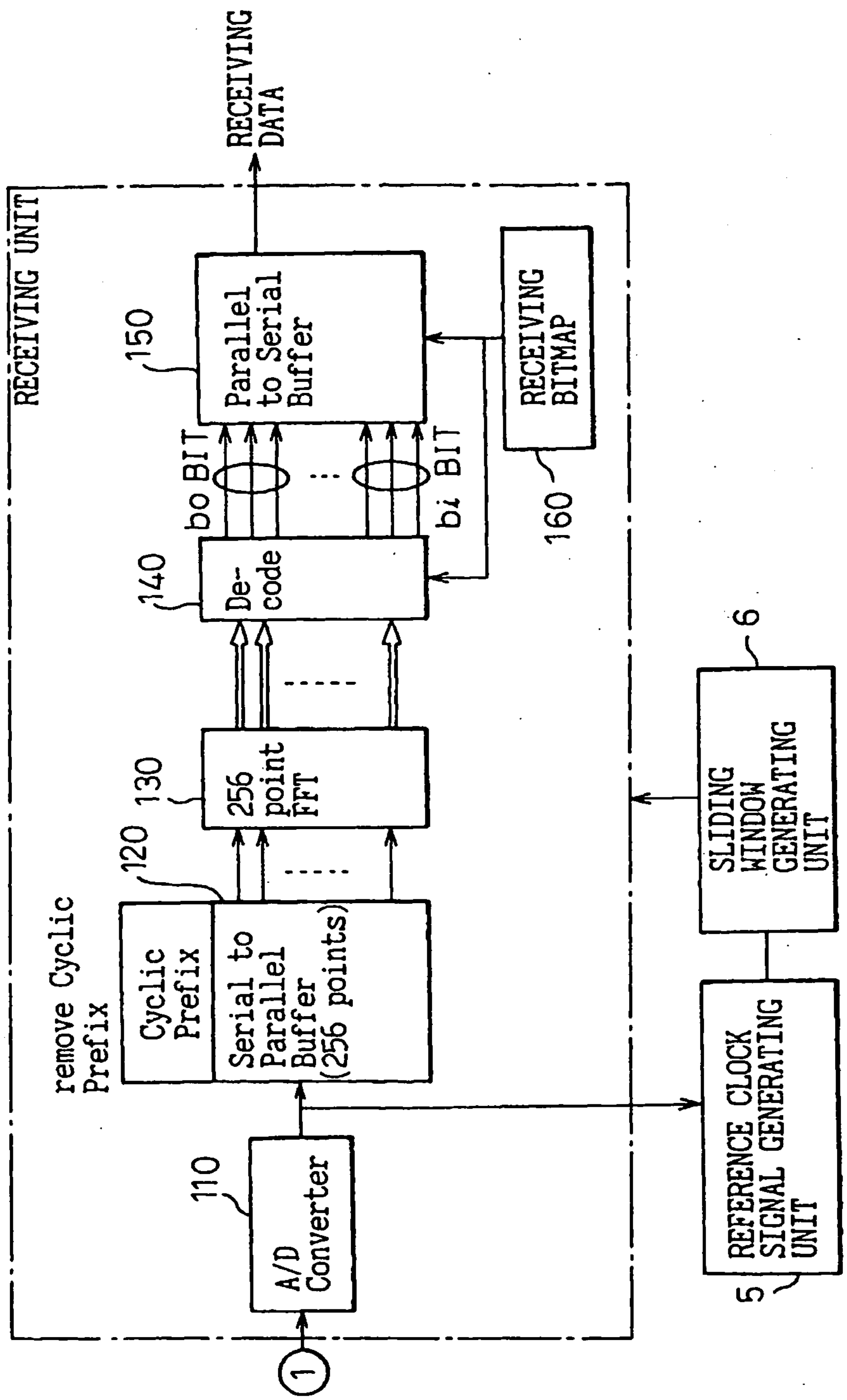

RECEIVING DATA
RECEIVING UNIT
150
Parallel to Serial Buffer
RECEIVING BITMAP
160
bo BIT
bi BIT
140
De-code
130
256 point FFT
120
remove Cyclic Prefix
Cyclic Prefix
Serial to Parallel Buffer (256 points)
110
A/D Converter
1
6
SLIDING WINDOW GENERATING UNIT
5
REFERENCE CLOCK SIGNAL GENERATING UNIT

Fig. 2

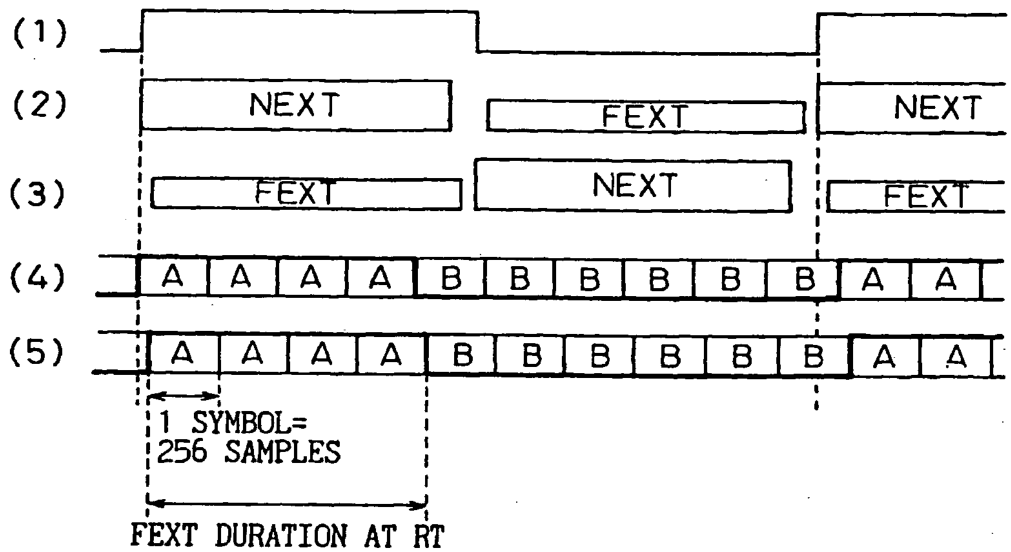

(1)
(2)
NEXT
FEXT
NEXT
(3)
FEXT
NEXT
FEXT
(4)
A A A A B B B B B B A A
(5)
A A A A B B B B B B A A
1 SYMBOL=
256 SAMPLES
FEXT DURATION AT RT

Fig. 3

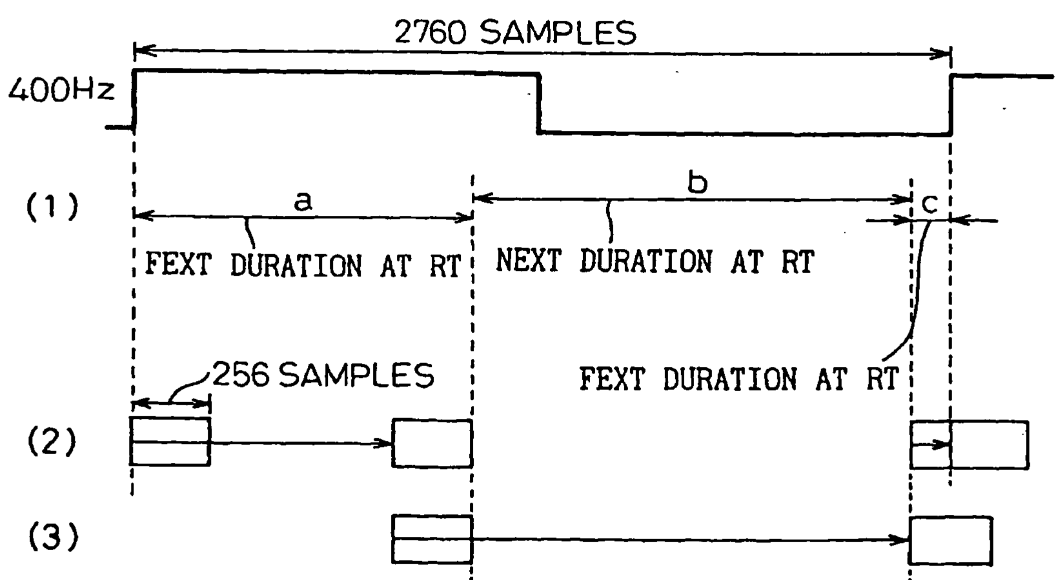

2760 SAMPLES
400Hz
(1)
a
b
c
FEXT DURATION AT RT
NEXT DURATION AT RT
256 SAMPLES
FEXT DURATION AT RT
(2)
(3)

Fig. 4

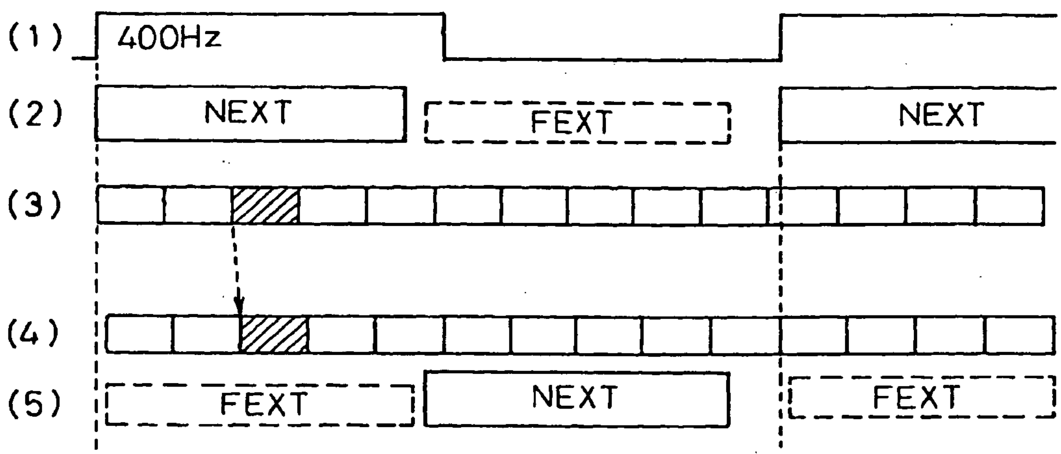

(1)
400Hz
(2)
NEXT
FEXT
NEXT
(3)
(4)
(5)
FEXT
NEXT
FEXT

Fig. 5

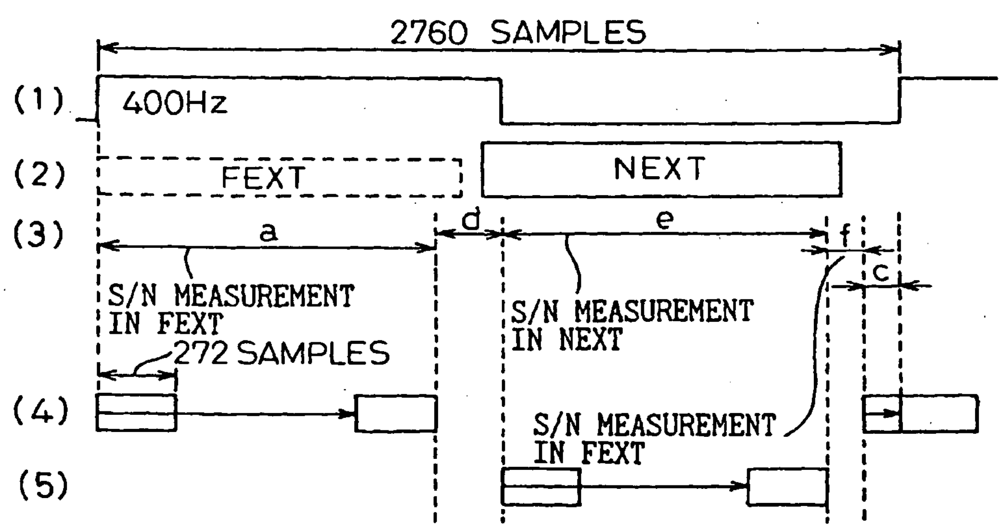

2760 SAMPLES
(1)
400Hz
(2)
FEXT
NEXT
(3)
a
d
e
f
c
S/N MEASUREMENT
IN FEXT
272 SAMPLES
S/N MEASUREMENT
IN NEXT
(4)
S/N MEASUREMENT
IN FEXT
(5)

Fig.6

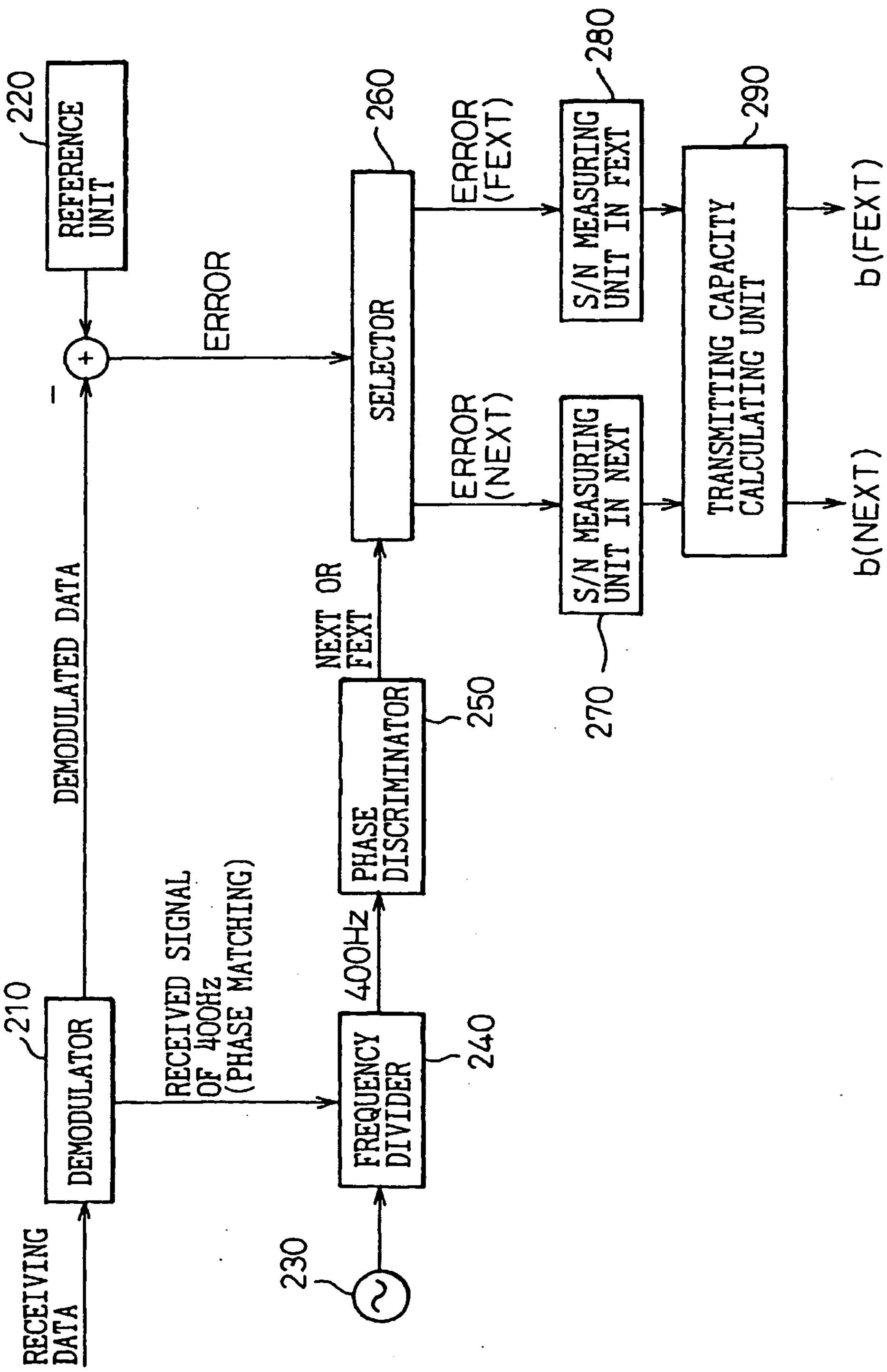

RECEIVING DATA
DEMODULATOR
210
RECEIVED SIGNAL OF 400Hz (PHASE MATCHING)
DEMODULATED DATA
REFERENCE UNIT
220
+
−
ERROR
230
FREQUENCY DIVIDER
240
400Hz
PHASE DISCRIMINATOR
250
NEXT OR FEXT
SELECTOR
260
ERROR (NEXT)
ERROR (FEXT)
S/N MEASURING UNIT IN NEXT
270
S/N MEASURING UNIT IN FEXT
280
TRANSMITTING CAPACITY CALCULATING UNIT
290
b(NEXT)
b(FEXT)

Fig. 7

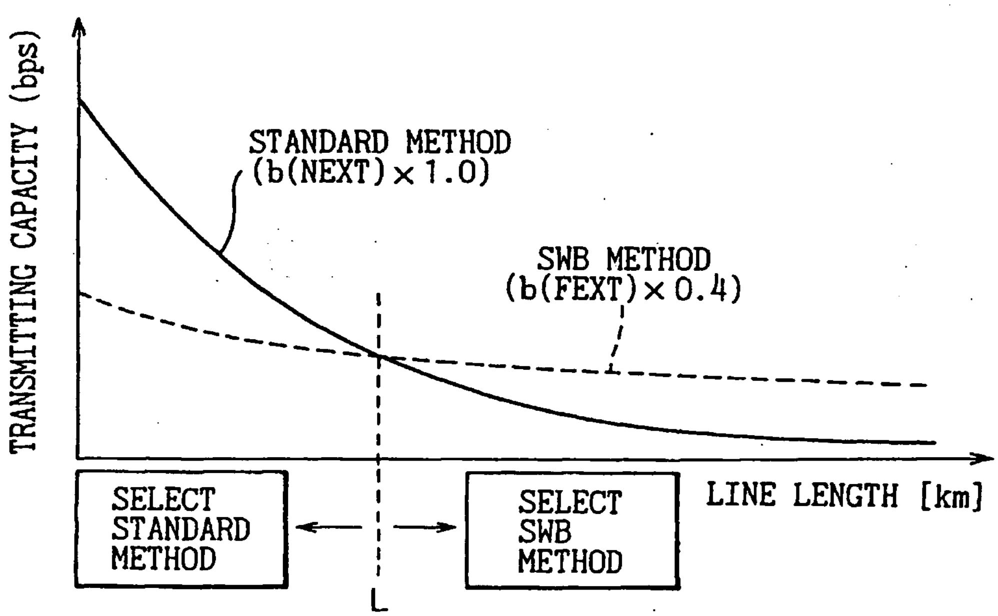

TRANSMITTING CAPACITY (bps)
STANDARD METHOD
(b(NEXT) × 1.0)
SWB METHOD
(b(FEXT) × 0.4)
LINE LENGTH [km]
SELECT STANDARD METHOD
SELECT SWB METHOD
L

Fig.8

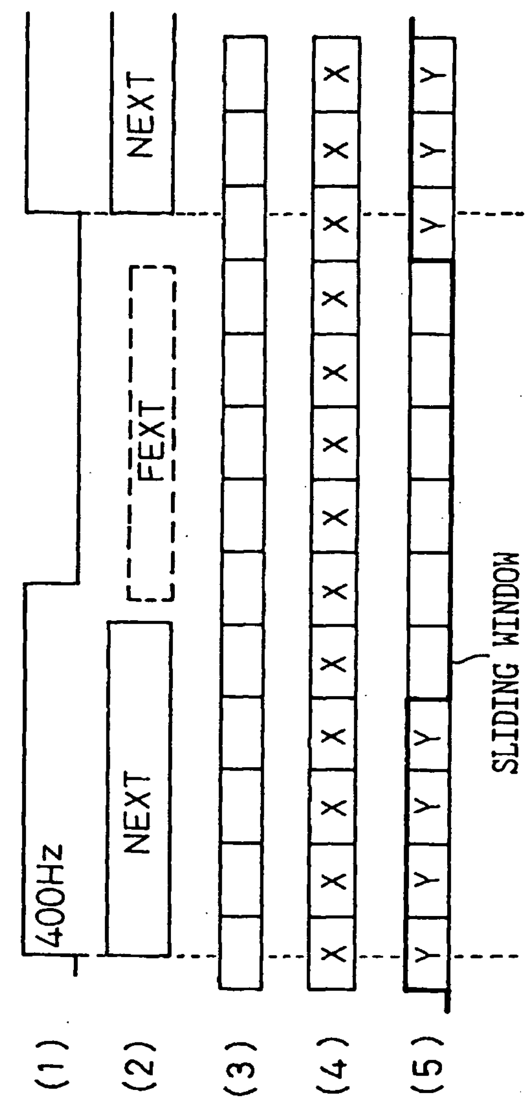
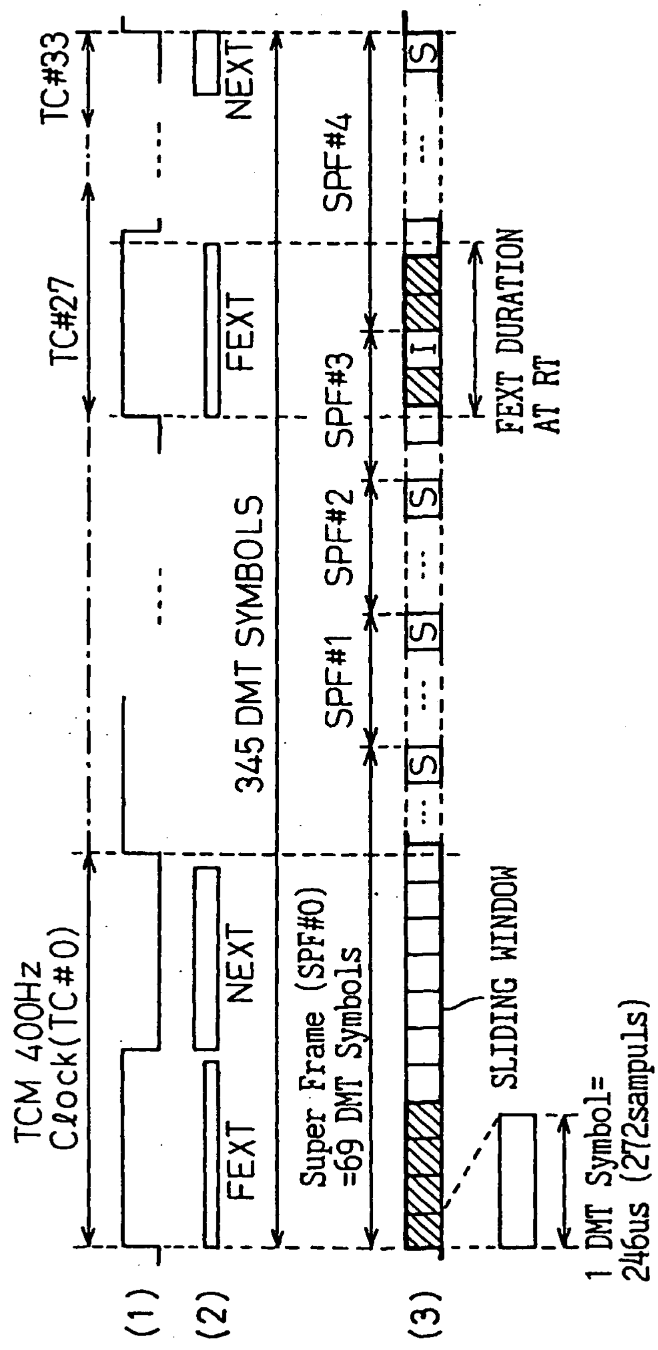


Fig.9



TCM 400Hz
Clock(TC#0)
TC#27
TC#33
(1)
(2)
FEXT
NEXT
FEXT
NEXT
345 DMT SYMBOLS
Super Frame (SPF#0)
=69 DMT Symbols
SPF#1
SPF#2
SPF#3
SPF#4
(3)
S
I
SLIDING WINDOW
FEXT DURATION
AT RT
1 DMT Symbol=
246us (272sampuls)

Fig.10

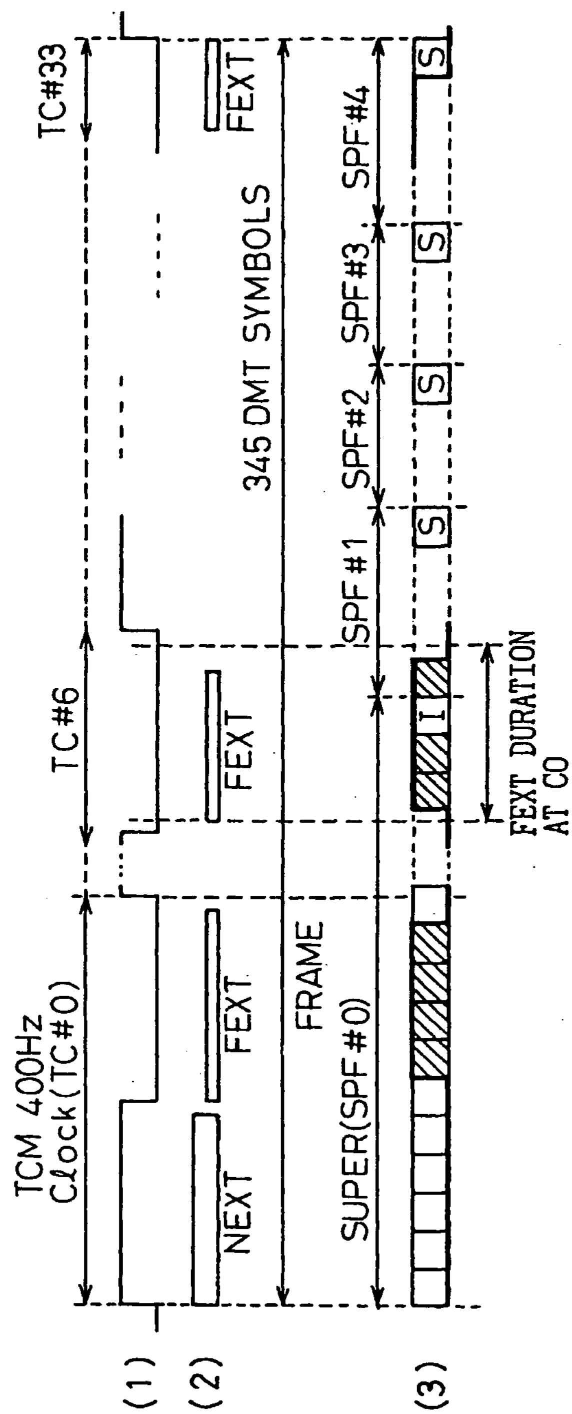

TC#33
TC#6
TCM 400Hz
Clock (TC#0)
(1)
(2)
(3)
NEXT
FEXT
FEXT
FEXT
345 DMT SYMBOLS
FRAME
SUPER(SPF#0)
SPF#1
SPF#2
SPF#3
SPF#4
S
I
FEXT DURATION
AT CO

Fig.11

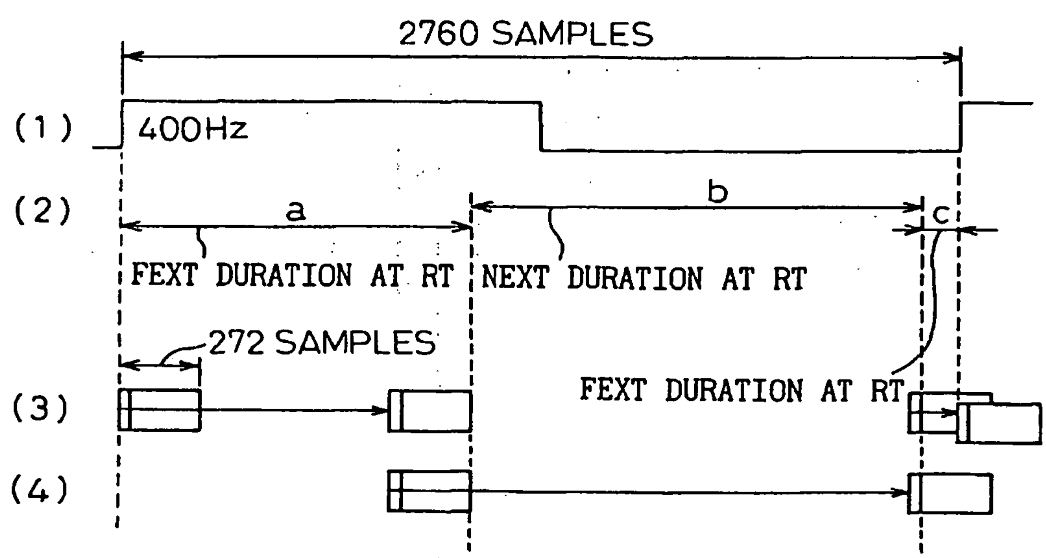

2760 SAMPLES
(1)
400Hz
(2)
a
b
c
FEXT DURATION AT RT
NEXT DURATION AT RT
272 SAMPLES
FEXT DURATION AT RT
(3)
(4)

Fig.12

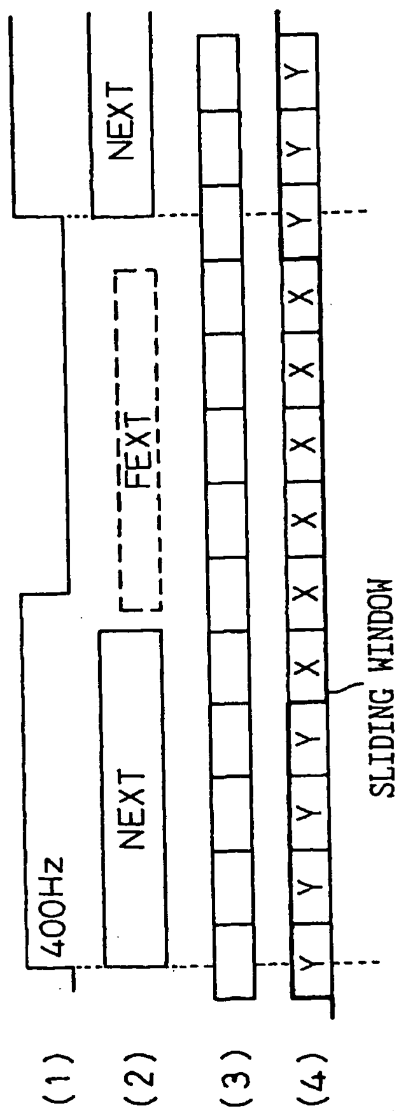


Fig.13A
PRIOR ART

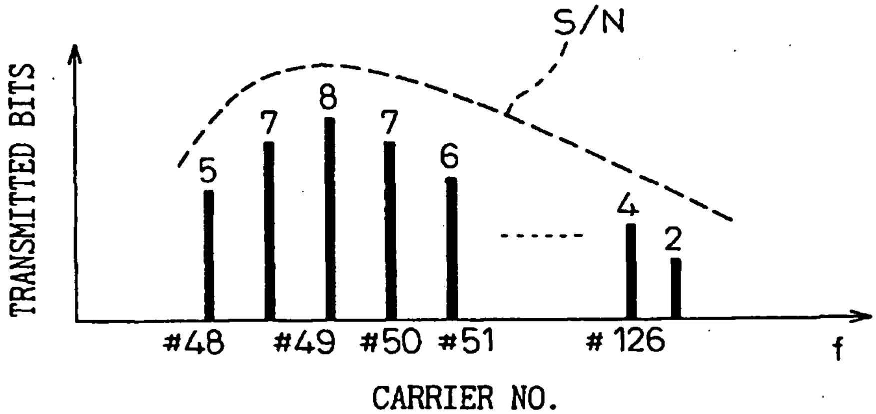


Fig.13B
PRIOR ART

CARRIER NO.i	NUMBER OF TRANSMITTED BITS bi
0	0
⋮	⋮
48	5
49	7
⋮	⋮

Fig.14
PRIOR ART

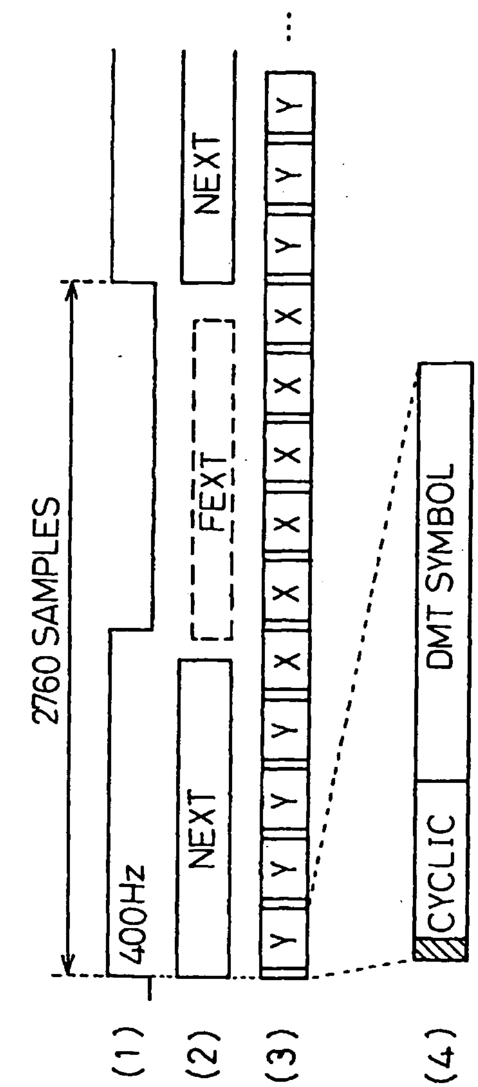


Fig.15